ANATOMY
OF
EYE AND ORBIT

GOLDNAMER

THE ANATOMY OF THE HUMAN EYE AND ORBIT

BY

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240 PAGES
6 ROENTGEN PHOTOGRAMS
51 BLACK AND WHITE ILLUSTRATIONS
8 PAGES OF COLORED PLATES
10 PAGES OF TABLES
MEASUREMENT CHARTS,
GLOSSARY,
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To My Honored
Father and Mother

WHOSE unselfish love for and devotion to their family and friends is ever present, and whose simple good deeds it is a pleasure to contemplate, this work is affectionately inscribed.

By the Author

FOREWORD.

This work on the anatomy of the eye has been undertaken and carried out with a full sense of the growing importance of the subject and the seriousness of the task. Without question, this branch of anatomy may nowadays be justly regarded as a major division of the science, meriting the most painstaking and exhaustive treatment in all of its details; and this is the spirit and method which have been brought to the work in hand.

In accordance with the modern conception of anatomy, whether of the body at large or of the eye, special emphasis is laid upon the developmental and functional significance of the parts, and their correlations, so that the vital interest of the student in the subject may be continuously sustained. Both writer and student must realize that this is a living subject, abreast of all the other advanced knowledge of the times, and that the relational architecture of the parts constitutes the foundation upon which the whole edifice of ophthalmology is erected. With this in mind, the instruction contained herein is presented in concise, logical, consecutive fashion, from the foundation up, and embodies that which, in the present state of our knowledge, represents established facts.

In order that the student may advance with the least possible time and difficulty to a broad understanding of the eye and its adnexa as something more than a mere visual apparatus, a sufficient grounding is given in the minute structural and functional anatomy of this organ, and the inter-relations between these aspects are clearly and logically shown, without imposing upon him the necessity of disentangling a mass of complex and confusing details. In this way I have tried to make these pages a useful summary of vitally interesting information for those who wish to attain a practical knowledge of the subject.

The terminology of anatomy has always been a source of more or less embarrassment. Many names were, in former times, given to structures and parts without knowledge, or in disregard, of their physical functions, so that many of these names are applied to several anatomical entities of diverse construction and

development. To remedy this anomalous condition of affairs there assembled at Basle, Switzerland, in the year 1895, a committee of scientists, who formulated and adopted a standard terminology known as the Basle Nomina Anatomica [abbreviated B. N. A.]. This nomenclature I have in some places indicated in brackets after the commonly-used names, and in others, where it seemed better usage, I have first given the B. N. A. term, indicating the common name afterwards in brackets.

In the descriptions contained in this book I have, in most instances, set forth what I understand to be the accepted conclusions of the best authorities, so as to give the student the benefit, in complete, concentrated form, of the net results of the work of numerous investigators, the fruits of long discussions, and the conflicting views of individual writers.

In my Bibliography I have endeavored to make reference to all from whom I may have derived any of my information, and I gratefully acknowledge their writings, to which I take pleasure in referring the reader for fuller discussion of controversial questions. The illustrations have been prepared with great care, and where any have been borrowed I have tried to give proper credit to their originators. If there are any omissions of references, they are unintentional.

I wish to express, here, my sincere thanks to my publishers for their more than kindly encouragement in the publication of this work, as well as for several material suggestions as to the contents of the book itself [e. g. the inclusion of the tables and glossary to be found at the back of the volume] which are of decided value to all students of ophthalmology.

THE AUTHOR.

Chicago, Ill.

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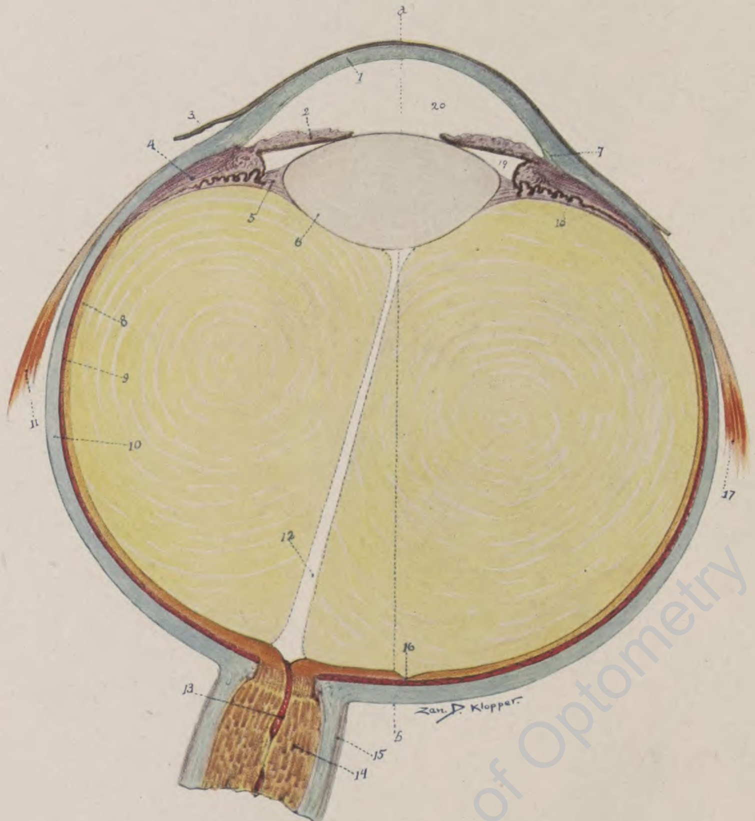


Bulbus Oculi

(1) Cornea. (2) Iris. (3) Conjuctiva bulbae. (4) Ciliary muscle. (5) Suspensory ligaments. (6) Lens. (7) Schlemm's canal. (8) Retina. (9) Choroid. (10) Sclera. (11) Rectus muscle. (12) Hyoloid canal. (13) Central vessels of optic nerve. (14) Optic nerve fibers. (15) Epidural space. (16) Fovea. (17) Rectus muscle. (18) Ciliary body and processes. (19) Posterior chamber. (20) Anterior chamber. a-b Optical axis.

CHAPTER I.

The Eye.

The organ of sight, known as the Eye, is situated in the anterior part of the orbit, where it is protected by the overhang of the bony orbital walls, and occupies about one-fifth of the intra-orbital space. It lies in a mass of yielding muscles, vessels, nerves and fasciae, surrounded by the orbital fat, all of which entirely fills up the orbital cavity.

The eyeball (bulbus oculi) lies about 2 mm. nearer to the lateral than to the medial wall of the orbit and somewhat nearer the superior than the inferior wall. The average distances are about, 4.5 mm. from the lateral wall; 6.5 mm. from the medial wall; 4.5 mm. from the superior wall, and 6.2 mm. from the inferior wall. The eyeball itself is irregularly spherical, because it is composed of two segments of unequal-sized spheres, the larger segment embraced by the sclera, comprising about five-sixths of the sphere; the smaller or corneal segment comprising one-sixth of the sphere. At birth the cornea comprises one-fifth of the sphere, instead of one-sixth as in adults, because of the fact that the foetal cornea is proportionately very much larger.

The cardinal diameters of the eyeball, in adults, are all about 24 mm. except that the vertical diameter is perhaps 1 mm. less. Myopic eyes have a longer, and hypermetropic eyes a shorter, axial diameter. At birth the eyeball is more uniformly spherical, and measures about 18 mm. in all diameters. This measurement increases about 3 mm. in each direction up to puberty, and at about sixteen years the eyeball reaches its full growth.

The male eye may be a trifle larger than that of the female, usually considered, about 0.5 mm.—but the diameters are very nearly equal in the two sexes. The apparent difference in the sizes of eyes in various individuals depends on the difference in the width of the palpebral fissure, the facial development, or the varying amount of the orbital fat. In young children the palpebral opening is wider proportional to its length, and moreover the overhang of the superior border of the orbital margin is not fully developed until about the twenty-fifth year. Hence the appear-

ance of largeness in children's eyes. The prominence of eyeballs also varies, according to the health of the individual, as well as the age.

The average weight of the eye is about 7.5 grams; its volume 7.8 cc. (Weiss gives 7 grams weight, and 6.5 cc. volume). Its specific gravity is 1.077. Quain says the globe weighs less than 7 grams and the volume is about 6.5 cc. The proportion of the combined weight of the two eyes to the body in the adult is about 1 to 4,900, whereas at birth it is about 1 to 500.

The Cornea.

Viewed from the front the cornea is horizontally elliptical; viewed from behind, it is almost circular. It forms the anterior one-sixth segment of the eyeball, and projects forward, having a radius of curvature of 7 to 8 mm. The cornea is transparent in health, and has a refractive index as compared with air of 1.333.

The cornea is generally regarded as being rounded on all sides, like a segment of a perfect sphere, but accurate measurements show this uniform roundness to be confined to the central 4 mm. of the cornea, while around this central 4 mm. the curves are subject to many aberrations and flattenings. This central curved portion, which may be considered as the section of principal vision, may be likened to the back of a spoon, the axis in one direction being greater than the axis in another.

Many authorities claim that all eyes are mildly astigmatic at birth; all agree, however, that changes in the shape of the cornea do take place from birth to old age, owing to many causes, such as disease, injury, and eye strain. Normally the cornea is more curved in the vertical than in the horizontal meridian. It is a curious fact that after seventy years of age there frequently occurs a perverse astigmatism, in which the cornea is more flattened vertically than horizontally.

The cornea is set in the sclera, like a watch crystal in a watch, so that the sclera overhangs the cornea about 0.5 mm. on its anterior margin. Therefore, incisions made in the sclera near the edge (or limbus) of the cornea are in reality mostly through the corneal tissue. The cornea measures about 12 mm. in its hori-

zontal and 11 mm. in its vertical diameter. These figures represent general averages, subject to variation of as much as 1½ mm. greater or less. The reason for the difference in measurements, anteriorly, is that the sclera overhangs the cornea more at the

CROSS SECTION OF CORNEA.

(1) Epithelium coat. (2) Bowman's membrane. (3) Stroma propia showing corneal corpuscles. (4) Decemet's membrane. (5) Endothelial coat.

upper and lower margins, while the inside diameters are usually reckoned at 13 mm. in all directions.

The normal thickness of the cornea, is about 1 mm. at the periphery, becoming gradually thinner toward the center, where it measures about 0.8 mm.

The average height of the apex from its chordal plane is 2.5 mm., but of course this is also subject to anatomic anomalies.

Where the cornea meets the sclera, on account of the differences in the two radii of curvature of these two segments, there is anteriorly a slight groove marking the junction point, known as the sulcus sclerae. The space adjacent to the cornea within a radius of about 1 mm. of this margin is known as the limbus.

All pathological changes in the cornea are characterized by reduced transparency. There may however be a cloudiness in an otherwise healthy cornea, known as arcus senilis, which is supposed to be a deposit of fat-cell-detritus around the limbus. This occurs usually in advanced age, and is generally an indication of vascular changes in other parts of the body; but it may also occur in younger persons.

The cornea is composed of five layers, called the:

(1) Epithelial Layer,
(2) Bowman's Membrane,
(3) Stroma Propria (cornea proper).
(4) Descemet's Membrane.
(5) Endothelial Layer.

(1) *The Epithelial Layer* is the outer layer, and consists of about six (6) strata of pavement epithelium, except that at the periphery of the cornea the layers are increased in number to about eleven. These layers are so evenly constructed, on the anterior surface, that light is reflected uniformly, so that the surface glistens when in health, and any disturbance of this regularly uninterrupted smoothness will manifest itself in loss of its shining transparency. The epithelial coat is in reality the continuation of the epithelium of the conjunctiva bulbae, having lost its connective-tissue sub-epithelial coat, or stroma of the conjunctiva bulbae, at the limbus. Its inner surface lies on a perfectly smooth membrane

known as Bowman's Membrane, without any connective tissue intervening, consequently it may be readily separated from its rather loose attachment. The lack of intervening tissue prevents a stretching of this epithelial layer, so that it is impossible, by suturing, to bring the edges of the interrupted epithelium together.

The layers of epithelium, beginning from the bottom, are designated as follows: (1) Foot cells, or Columnar cells, having a perfectly flat base which rests firmly on Bowman's Membrane. These are by far the largest cells of this coat, their rounded heads being in apposition with the next layer of cells above it, known as (2) Pologonial cells (fingered cells of Cleland); these are generally connected posteriorly by projections that dip down between the lower cell interspaces. (This division of cells is two or three cell-layers deep.) (3) The Superficial cells (which consist of two or three cell-layers) are flat cells, which retain their nuclei and do not undergo that hardening and desquamation which similar cells undergo elsewhere, as in the epidermis.

The lymph spaces of the epithelial coat, and the nerves, are found in the interspaces of the epithelial cells: the general endings of the nerves in this layer are both by the end-bulbs of Krause and in fine branching fibrillae. These nerve endings are all non-medullated, and therefore extremely sensitive to irritation.

While the epithelium of this layer cannot be stretched by suturing, it is quickly replaced by rapid proliferation, and in a surprisingly short time will travel over a very large area, in an effort to repair its interrupted edges, so that in penetrating wounds of the cornea the epithelium will be found very quickly entering the anterior chamber.

(2) *Bowman's Membrane* is an elastic membrane, apparently structureless; it is usually considered as being nothing more than the anterior lamellae of the cornea propria, without the presence of the characteristic corneal corpuscles. Certain pores through this membrane afford transmission for the nerves to the epithelial layer. This membrane does not renew itself when its continuity is interrupted. When approaching the edge of the cornea, it thins down to an acute angle, and entirely ceases at about 1 mm. from the corneal periphery.

(3) *The Stroma Propria* (Substantia Corneae) consists of a modified connective tissue placed in even layers or lamellae, lying perfectly parallel, and numbering about 70 even rows, which are continuous with the lamellae of the sclera. The lamellae are united by a cement-like substance, through which are interspersed the fixed cells of the cornea, known as the corneal corpuscles, having regular nuclei and long processes which stretch out to connect with the adjoining corneal corpuscles.

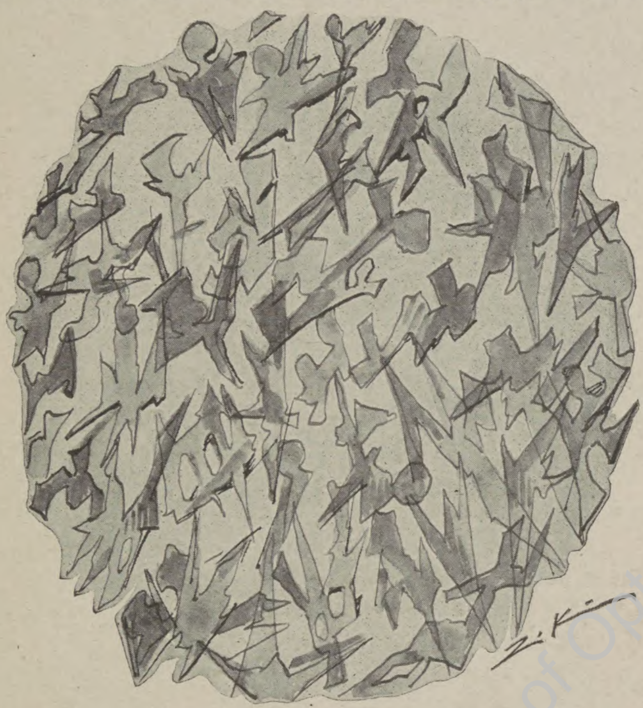
Fuchs has shown that the human corneal corpuscles are not like those of most animals, i. e., cells with tree-shaped prolongations, but are more like a protoplasmic net-work of flat ribbon-shaped projections, in which the cell nuclei are seen here and there.

You will also note, in this picture, the motile cells, or wandering cells, called the cells of Recklinghausen, are nothing more than white blood corpuscles in the lymph channels.

The stroma propria constitutes about nine-tenths of the corneal substance, and while the lamellae are all parallel to the surface and to each other, there occurs a dipping down of these lamellae at intervals, so that one lamella will be found on a lower plane in some sections than in others. These interwoven lamellae dip down at long intervals, and at a very obtuse angle, so that the interruptions to the regularity of the parallel layers are negligible.

The stroma propria is found to be thicker at the periphery than at the center. This is probably to be accounted for by the post-mortem swelling of the lamellae, since this tissue is very apt to take on osmotic changes at the periphery at the time of dying, especially as this is where the lymph enters and leaves the interlamellar spaces. The nutritional supply of the stroma propria, in common with all the coats of the cornea, is by means of osmosis of lymph through the interspaces, wherein lie the fixed corpuscles (some authors have found lymph corpuscles in these spaces), as the capillary loops of the marginal arteries and veins stop short, when they have penetrated about 1 mm. into the periphery of the cornea, elsewhere described as the limbus. This loop area is mostly made up from the anterior ciliary arteries and veins, which

course through the conjunctiva and episcleral tissues, while the deeper structures of the limbus are poorly supplied with capillary loops. The reverse is true of the nerve supply of the corneal



CORNEA.

SURFACE VIEW OF FIXED CORPUSCLES OF MAN.

Showing the corneal corpuscles with their thickened processes, which processes differ from those of other vertebrata in being shorter, less numerous and not so slender. The nuclei do not stain to show the marked differentiation of structure. The overlapping is because of the impossibility of procuring a section from a single inter-lammelar space, so that the picture is of several super imposed spaces. Picture from Fuch's American Lecture, 1922.

tissue; the larger branches enter the deeper structures, and the more sparse branches enter the superficial layers.

Some authors have claimed that there is a fine system of lymph channels accompanying the fixed corneal corpuscles, which

may be demonstrated by injecting colored fluids. Parsons, on the other hand, says it has been definitely proven, even in foetal life, that the cornea is at no time vascularized. This last statement, however, does not agree with my understanding of the embryology of this structure.

Modern methods of examining the corneal stroma through the Corneal microscope, with the Slit lamp attachment, have demonstrated that in cases of interstitial keratitis the vessels remaining after such changes, which we have heretofore regarded as simple gray lines, are in fact patulous vessels with a potential lumen, through which single lines of red blood corpuscles may be seen to pass; further investigation in the living eye with this instrument possibly may also demonstrate a definite canal system of lymph-carying vessels in the corneal structure.

The nerves, on entering the cornea, lose their medullary sheath very near the limbus, and spread out into fine fibrillae, which end, toward the corneal summit, in among the intercellular spaces of the epithelium, so that any erosion of the epithelium will leave bare these non-medullated fibres.

Corneal Nerves.

As might be expected from its exceeding sensitiveness, the cornea possesses a highly-developed and intricate nerve supply. From the Anterior Ciliary Nerves are derived nerve fibres which not only supply the cornea, but send branches to the iris and ciliary muscle, near the limbus or sclero-corneal margin, there to form a dense plexus called the Plexus Annularis. This plexus contains both medullated and non-medullated fibres, and from it are derived the penetrating branches into the Uveal Body. The corneal fibres are variable in size, containing anywhere from three to twelve filaments. Of the number which penetrate the Cornea totaling about eighty, more than half (five-eighths) pass to the anterior surface, and less than half (three-eighths) to the stroma corneae, the anterior division containing more of the medullated variety. About 1 mm. from the limbus all the filaments become non-medullated and therefore transparent. These are distributed in an intricate network throughout the corneal tissue, especially in the anterior portion of the corneal tissue. The anastomosis or network junctions are so numerous that ganglion cells have been supposed to be situated at the crossing points; as yet, however,

they are not demonstrable. This set of nerves supplies the sub-epithelial plexus, which in turn supplies the intra-epithelial plexus, which in turn supply the endings known as Krause's Bulbs, or the round nodular enlarged endings. In addition to these nerve plexuses, there is another plexus known as the Superficial Stroma Plexus, in contra-distinction to the Deep Stroma Plexus, just described. This superficial stroma plexus receives branches from the *deep* plexus and its penetrating branches, and from the conjunctival branches. This plexus is found beneath Bowman's membrane, and sends delicate fine fibrillae, pointed or thickened, in among the epithelial cells; these are all non-medullated delicate fibres.

The lamellae of the cornea are continuous with those of the sclera; the only difference noted is that at the sclera the stroma loses its transparency and regularity of arrangement, and that the bundles are not so evenly placed in their relation to the corneal corpuscles. In extreme age, on account of the cloudiness at the limbus (arcus senilis), and consequent lessening of the transparency there, the cornea appears much smaller than in younger subjects.

(4) The inside limiting membrane is known as *Descemet's Membrane*. This is an elastic, homogeneous glass membrane, of a hyaloid character. Its difference in parenchymal construction classes it as quite distinct from the other corneal constituents. For this reason it often happens that when the cornea is broken down by ulceration and pus, Descemet's membrane, on account of its different chemical constituency, will be unimpaired by the superficial pathology. However, when injured, this membrane will regenerate itself slowly. When divided, it tends to curl inwardly away from its attachment to the corneal stroma. Descemet's membrane is thinner in youth than in old age, and as the years advance it becomes twice as thick throughout, showing, near its border, folds, or undulating projections (so-called wart zone), on the inner surface of the cornea, which are distinctly noticeable under its endothelial covering.

This membrane also, like the superficial (Bowman's) membrane, stops short of the limbus about 1 mm.; unlike Bowman's

membrane, however, it does not entirely cease, but fuses into the radiating bundles of the elastic fibres which go to form the Pectinate Ligament. Another change of Descemet's membrane at the periphery is that it thickens to meet the triangular apex of the pectinate ligament. This thickening of Descemet's membrane from the center toward the periphery amounts to about 1/10 of its thickness, which measures at its center about 0.010 mm.

(5) *The Endothelial Layer* forms the posterior or inner layer of the cornea. It consists of a single layer of endothelial cells, which are nucleated, flattened, hexagonal cells, very rich in protoplasm. This layer coats perfectly the whole of Descemet's membrane, and is continuous around through the angle of the anterior chamber to the iris; in fact it forms the anterior layer of the iris. (This is the posterior epithelium layer of Fuchs, who no doubt adopts that name on account of the structural make-up and embryological derivation of these cells, observing them to be more like epithelial than endothelial cells.) The regularity of this layer is interrupted on reaching the limbus by the open spaces in the pectinate ligament, and in its further extension over the anterior part of the iris the close approximation of the edges of the cells, such as occurs over Descemet's membrane, is not again resumed; so that, while the cells form a lining for the pectinate ligament and the anterior surface of the iris, it is more like a meshwork than a homogeneous membrane.

The proper functioning of the cornea depends greatly on its position between two watery secretions, the tears and aqueous, which constantly moisten its two surfaces.

The Sclera.

The Sclera (Fasciculus Bulbi) is the main supporting envelope for the posterior five-sixths of the eyeball. It is named sclera (meaning hard) from its indurated, or hardened connective-tissue character. This connective-tissue element occasionally contains branched pigment cells (chromatophores). In dark-skinned people, especially, these pigment cells give the scleral tissue a dark slate-colored appearance. This dark coloration is especially noticeable around the canals, or emissaria, of the anterior ciliary arteries and veins.

The sclera measures about 1 mm. in thickness at its posterior pole; at the equator it measures about 0.5 mm., and at its junction with the cornea it is about 0.6 mm. thick. Under the insertion of the tendons of the recti muscles, it is thinner perhaps, than in other portions, but the tendons here reinforce the sclera, possibly because they are histologically composed of the same fibrous tissue. The sclera is thinner in childhood than in adult life. This is well shown by the bluish appearance of the sclera in babies, caused by the choroid showing through it.

The sclera consists of white fibrous tissue, interlaced with some elastic fibres. These fibres are gathered in bundles, which take most varying directions, dipping in between each other; mostly at right angles, however with the main trend in the equatorial direction. In two places, near the limbus and near the cribriform plate, the equatorial direction is the only direction taken by the fibres. Numerous migrating connective tissue and pigment cells are found irregularly throughout the scleral tissue, with the fixed cells of the scleral tissue very irregularly placed.

The sclera is pierced by many vessels and nerves, but it has few vessels of its own, receiving its nutriment from the perichoroideal and super-scleral arteries, while its veins empty into the anterior ciliary veins and into the vena vorticosa.

The nerves of the sclera, which are few, are derived from the ciliary nerves, which pass into the intervals of the fibrous bundles, and end in some unknown manner—perhaps, as in the stroma corneae, by long tortuous fibrillar endings. The anterior part of the sclera is supplied by posterior branches of the anterior nerve group which supplies the cornea.

The outer surface of the sclera has fibrillar attachments with Tenon's capsule, which envelopes it and is reflected around all the muscles that are attached to it, so that, when the sclera is stripped away from the capsule, the broken fibrillae give its surface a somewhat shaggy or roughened appearance. The non-uniform reflection of light from this roughened surface gives it a dull white appearance, whereas the tendons of the attached muscles, whose bundles are all parallel and uninterrupted by irregular transverse fibrils, glisten.

Externally, the sclera is covered with flattened endothelial cells, which are continuous internally with the walls of the emissaria of the blood vessels, passing through the scleral tissue, so that it is generally recognized that the episcleral, or Tenon's, space is in direct communication with the perichoroidal space, and contains lymph.

Internally, the color of the sclera is changed by the deposit of chromotophores in the sub-scleral tissue, the color being known as the Lamina Fusca. The pigment deposits are very irregular, being found in the posterior pole more than forward, while near the anterior border of the sclera it fades out altogether.

The interior surface of the sclera is marked with grooves, in which the ciliary vessels and nerves are found, especially on each lateral side, where travel the long ciliary arteries with their escorting nerves.

The sclera thickens somewhat in old age but this does not apparently affect the volume of the intraocular contents. In extreme old age, moreover, there is usually a fatty degeneration, with deposits of fat in the outer or episcleral tissue, which causes the sclera to appear yellowish. This is especially noted near the sclero-corneal margin.

The anterior section of the sclera is covered by the conjunctiva, with its sub-conjunctival tissue, under which there is a poorly defined episcleral connective tissue, through which course the anterior ciliary vessels, forming a thick capillary net around the limbus. At the junction of the sclera with the cornea, as previously explained, there is a well-defined groove, which is partially filled out by the combined thickness of the episcleral tissue and layers of the corneal epithelium. Here the layers increase to about 11 in number and may appear darker, on account of being packed closer together. The scleral stroma differs from the corneal stroma, at its junction, only in the fact that it is opaque, while the corneal stroma is transparent; the stroma of the one is continuous with that of the other, without a distinct line of demarcation.

The posterior wall of the sclera at the corneal margin shows a splitting, or turning back of a small spur, called the Scleral

Roll. To the posterior side of this spur is attached the origin of the ciliary muscle; while the split anterior portion forms the posterior angle of a canal, known as Schlemm's Canal. The outer wall of this canal is formed by the scleral tissue, the front angle by the corneal tissue, and the inner wall by the pectinate ligament. The pictinate ligament is a loose meshwork which fills and rounds out the angle of the iris; it connects Schlemm's canal and this anterior chamber by the meshwork spaces, known as the Spaces of Fontana. Schlemm's canal is usually not a single tube, but a tube with many deviations, dividing into two or three canals, and reappearing again as a single tube. There is, indeed, no well-defined wall for this canal, but the lumen seems to be at least partly lined with a sparse endothelium. Its connection with the anterior chamber is through the spaces of Fontana, while its outward anastimosis is supposed to be through its connection with the anterior ciliary veins.

The anterior ciliary veins and arteries pierce the sclera near the canal of Schlemm, which, on account of their great number, and the thinness of the sclera at this point, makes this region one of the weaker sections of the eye, as is sometimes demonstrated when traumatic pressure is exerted on the ocular tissues. Before leaving the pectinate ligament it would be well to state that filaments from Descemet's membrane are incorporated with the filaments of this ligament, so that the strengthened strands of the ligament, as they join the anterior border of the scleral roll, act as an anchor against the posterior pull of the ciliary muscle, which, as stated, arises from the posterior border of the roll.

The insertions of the recti muscles in the sclera can be seen rather plainly. The tendinous tissue of these tendons cannot be differentiated from the scleral tissue, except that the fibre of the tendons assumes a perfectly straight course and disappears gradually into the scleral tissue. The muscles are covered and surrounded by the sheath of Tenon, by which they are connected with the loose trabeculae, also found in the episcleral space. Behind the equator are the insertions of the oblique muscles, which will be discussed later. The anterior ciliary vessels accompany the recti muscles and enter the episcleral and scleral tissue in front

of their tendinous insertions, while some branches turn backward at the insertion of the recti muscles, to feed the episcleral space, posteriorly, toward the equator.

The sclera is pierced externally a short distance posterior to the equator (about 6 mm.) by the emissaria for the vortex veins (venae vorticosae), which are loosely attached in these emissaria. These openings have an oblique course, which measures in the sclera from 3.5 to 4.5 mm., and, like the anterior ciliary vessel emissaria, are more pigmented than the surrounding tissue. The direction of the vortex veins in the sclera is from before, outward and backward, while the loose connection with the emissaria allows a stretching forward of these veins, when drawn forward with the choroidal coat, to which they belong.

The posterior segment of the sclera, around the insertion of the optic nerve, consists wholly of equatorial fibres.

On reaching the nerve head, the sclera splits into two segments, one of which continues across to fuse with the scleral filaments from the opposite side; this is the smaller segment; the filaments of this segment separate into a sieve-like mesh, through which pass the filaments of the optic nerve, and also the central vessels of the optic nerve, forming what is known as the Lamina Cribrosa, or cribriform plate, or the optic disc. Some of the fibres that enter the lamina cribrosa take a posterior direction, to be incorporated in the sheaths of the nerve bundles which go to make up the optic nerve. The optic nerve entrance is about 3 mm. to the nasal side of, and 1 mm. below, the posterior pole of the eyeball.

The larger segment, which consists of about two-thirds of the thickness of the scleral tissue, on reaching the optic nerve, bends posteriorly, and is continuous with the outer sheath of the optic nerve; in fact, it again splits into a thicker outer portion, which blends with the dural coat of the optic nerve, and a thinner inner portion, which is continuous with the arachnoid coat of the same. The space between the two coats is known as the outer intravaginal space, and is a potential lymph space; this space has its anterior blind end wholly within the scleral tissue. The inner (arachnoid) coat is also separated from the pial sheath by a po-

tential space. These optic nerve coats will be more fully described when the orbital portion of the optic nerve is taken up.

The short ciliary arteries and nerves enter their respective emissaria which lie concentrically about 3.5 mm. around the entrance of the optic nerve. There are about 20 such emissaria, through each of which pass one artery and one nerve. Before entering the emissaria the arteries each give off a branch, supplying the episcleral space on the posterior section of the globe. The directions of these emissaria are variable; some are straight, while others are inclined somewhat toward the optic nerve. The vessels, while in their respective emissaria, give off branches into the sclera proper, which form a vascular circle around and in the optic nerve head, and send branches posteriorly, to anastimose with branches of the central vessels of the nerve. This vascular ring is known as the vascular circle of Zinn (Circulus Vascularis Nervi Optici), and is the only anastomosis made by the central vessels of the optic nerve with any other intra-ocular vessels.

Somewhat away from the entrance of the short ciliary vessels are two openings, one on either side, about 4 mm. from the entrance of the optic nerve, for the entrance of the long ciliary arteries and nerves. These emissaria pierce the sclera in a very long oblique manner, forming a curve with the concavity inward, and are about 7.5 mm. in length. The nerves divide, while in the canal, into two branches, so that at the internal exit there are two trunks. The nerves are connected loosely by fibrillae to one wall of the emissaria.

CHAPTER II.

The Choroid and Iris.

The choroid or the middle coat of the eyeball is the pigmented, chocolate-colored, or black, coat of the eye. It consists mostly of vessels, for the nourishment of the retina and the secretion of the fluid humors of the eye, and constitutes the principal venous pathway from the eye. The choroid, from its color, is known as the Uvea (grape), and the different divisions of this coat, taken altogether, are known as the Uveal Tract. The choroid is divided, for descriptive purposes, into three well-marked sections, known as the Choroid, the Ciliary Body, and the Iris.

The choroid coat has five layers, named from the outside:

1. The Supra Choroid.
2. The Layer of Large Vessels.
3. The Layer of Medium-Sized Vessels.
4. The Chorio-Capillaris.
5. The Lamina Vitrea.

The outer surface of the choroid is in loose apposition with the inner surface of the sclera, the space between being a potential space or lymph canal, intercepted by many small pigmented trabeculae; and known as the Supra-Choroidal Space. This space is limited anteriorly by the insertion of the ciliary muscle, and behind by an oval attachment of about 5 mm. diameter, encircling the Optic Disk and the Fovea Centralis.

The supra-choroidal space is traversed by several vessels, all of which take a general anterior-posterior direction, and are loosely imbedded in the lamellae. These lamellae are distributed throughout the whole space, seemingly belonging as much to the subsclera as to the supra-choroidea. They are of elastic connective tissue, quite densely pigmented by the chromatophores, which, as mentioned, are sparsely found in the scleral tissue. These chromatophores are rather large-sized, dark-pigmented, branched, connective tissue cells, with many pigment granules, and a lighter pigmented nucleus. There also occur here melanus cells, one of the two places in which these cells are found normally in the body. The distribution of these chromatophores, while greater here than

in the supra-choroidea, is found in all the coats of the choroid up to the chorio-capillaris; this capillary coat contains very little pigment.

The pigmentation of the supra-choroidea stops short at about the position of the ora serrata.

The layers of the supra-choroidea have been numbered variously by many authors; however, as they are usually of strands that intertwine longitudinally, the numbers will vary with each section examined, as some of the fibrillae will tear off longer than others. The supra-choroidal space is lined with endothelium, and is one of the lymph spaces of the eye. It connects, through the emissaria for the vortex veins, with the episcleral space; this makes an available route for metastases of pathological conditions.

After the supra-choroid coat (if this may be considered a coat) we have the three vessel-layers, the Layer of Large Vessels, the Layer of Medium-Sized Vessels, and the Choro Capillaris, or the Layer of Capillaries; on the inner surface we have the Lamina Vitrea.

(2) The layer of large vessels consists of the larger venous vessels. These are interspersed with elastic connective tissue, which is densely pigmented.

(3) The layer of medium sized vessels consists of the smaller veins, and the short ciliary arteries. The pigment fades somewhat, or is less dense, in this layer. The short ciliary nerves, while traveling through this layer, give off motor branches, which are distributed outwardly into the supra-choroidal space.

(4) The chorio capillaris, or capillary layer, is unpigmented. The vessels lie so close together that the lumina of the capillaries are larger than the interspaces. While the choroid has many nerves passing through it, there are apparently no sensory nerve fibres ending here, so that inflammatory conditions of the choroid are devoid of pain, and where pathologic changes are indicated by pain it is quite certain that other surrounding tissues are involved.

In many animals an iridescence is seen in the choroid, which is designated Tapetum. This is a deposit of iridescent cells in the capillary sub-stratum, or between these and the internal elastic

layer. Perhaps some such cells are noted by the ophthalmoscope, when a so-called choroiditis is occasionally diagnosed.

The thickness of the choroidal vessel-layers, which in reality comprise the whole thickness of the choroid, is about 0.25 mm. throughout; this thickness is best brought out by injected specimens, because the veins are usually empty post mortem.

(5) The lamina vitrea, or glass membrane, is no doubt a surface collection of the various filaments of elastic tissue and connective tissue that is found in the interspaces between the whole vessel-layer area, in which area the elastic fibres, with connective tissue and glass membrane tissue intertwined, constitute the stroma of the choroid. This membrane, when reaching the surface of the choroid, may be considered as really two membranes. The outer one, on which is seated the pigment epithelial layer of the retina, is a true homogeneous glass membrane. This is certified by the peculiar stains necessary to demonstrate a glass membrane, also by the fact that it is subject to the thickening and nodular degeneration which occurs in the aged. This nodular thickening may often be diagnosed in the living eye by the peculiar yellowish rounded areas noted by the ophthalmoscope. The outer portion of the lamina vitrea is less markedly a homogeneous coating, but is a mixed, elastic, fibrillar, superficial mesh, which continues forward, and constitutes, in my opinion, the original fibres of the suspensory ligament of the Zonule of Zinn, while the deeper intra-vessel portion constitutes the final intra-vascular insertion of the ciliary muscle, which disappears in fibrillae at the choroidal insertion, in the so-called stroma of the choroid coat.

The ciliary region (about 6 mm. broad) of the choroid commences at the ora serrata, and ends at the anterior chamber, or at the base of the ciliary muscle, which helps to make up a boundary of the angle, or part of the rear wall of the anterior chamber.

This region may well be divided, for descriptive purposes, into three portions: The Orbicularis Ciliaris, the Ciliary Body with the Ciliary Processes, and the Ciliary Muscle.

The orbicularis ciliaris is the band of flattened choroid, about 4 mm. wide, situated at the anterior margin of the choroid, com-

mencing at the ora serrata. This zone is perhaps 1 to 1.5 mm. broader on the temporalward and inferior sides than on the nasalward and superior sides. The orbicularis ciliaris is shown by radiating ridges which are slightly grooved. In these ridges are the vessels of this portion of the uvea, which have a straight course forward. This portion of the choroid is composed of the medium-sized vessels, with arteries intermingled, and none of the chorio-capillaries. It takes on a marked pigmentation where it emerges from the confines of the ora serrata; where, before, it was brown in color, it now becomes black.

The ciliary processes begin at the front of the orbicularis ciliaris and number about 70 longitudinal ridges. While somewhat irregular, they generally are of two sizes; the smaller measure about 2 mm., the larger (comprising about two-thirds of the number) are about 0.5 mm. longer.

The space between the ciliary processes and the lens in the normal eye is about 0.5 mm. wide all around. In hypermetropic eyes, with thicker circular fibres of the ciliary muscle, it may be supposed that this space is less than in myopic eyes; moreover, in venous stasis, partial or complete, from whatever cause, one may well imagine a predisposition to glaucoma. (Idea quoted from Otto Wipper's article on Glaucoma.)

The ciliary prominences are about 0.75 mm. high. When looked at from the anterior surface, these ridges show on their crests a lighter aspect than the valleys, which are in shadow. The valleys appear really darker than they are, as they are equally light when spread out. The valleys are the routes taken by the lens suspensory fibres, to their insertion back in the choroid lamina elastica. They also have on their floor small excrescences, or folds, which are to be seen by a magnifying glass, and are arranged in two or three broken rows. These are found in each valley of the ciliary process zone.

On the outer margin of the ciliary processes of the orbicularis ciliaris is found the ciliary muscle, which is a non-striated muscle, having its origin at the posterior surface of the scleral roll, while its insertion is in the choroidal stroma, as stated above. This muscle, seen on section, is a triangular muscle which forms about

one-half the triangle made up by it and the ciliary body proper. The base of the muscle is toward the anterior chamber.

The ciliary muscle contains meridianal fibres, which are the longitudinal ones, and are the more numerous, while some of these fibres bend around in a circular manner (sometimes called Mueller's Muscle). The circular portion of this muscle is much better developed in hypermetropic than in myopic eyes. This circular portion is incorporated in the tissues of the ciliary process portion of the uvea, so that the contraction of the ciliary muscle not only draws the choroid forward, but tilts forward the back ends of the ciliary processes, to which the anterior ligaments of the lens are partly attached. The anterior capsule of the lens is thus more loosened than the posterior capsule, to allow more expansion in the anterior part. It is known that most of the posterior fibres run in a forward manner, to be inserted in the anterior capsule, while the anterior and middle fibres are attached in the posterior portion and at the equator.

The supra-choroidal space separates the ciliary muscle from the sclera, up to its front attachment at the scleral roll, so that the supra-choroidal space comes right up to a line drawn flush with the front surface of the Iris. The length of the meridianal, or the longer side of the ciliary muscle, from its origin to the insertion in the choroid, is the same as the rest of the ciliary zone—about 6 mm. It will thus be seen that the ciliary muscle from its attachment and origin, is the chief agent of accommodation.

The connective tissue of the uveal stroma, throughout, is thickened in later life, so that, particularly at the ciliary processes, where this thickening is normal, and by reason of its encroachment on the circumlental space, it assumes a pathological importance.

Throughout the uveal tract, here as well as in the choroid, is found the stroma of the medium sized vessels, with the accompanying connective tissue mixed with the glass membrane or elastic fibres, among which vessels are found the chromatophores, the pigment that gives the uveal tract its color.

The glass membrane, or stroma elastica, as in the choroid proper, accumulates at and spreads out on the surface, where it

becomes the glass membrane of the uveal tract, on which surface the pigment coats of the retina extend forward. The pigment layer of the retina is the only layer of that coat (retina) which advances beyond the ora serrata. Before leaving the ciliary processes, it might be well to mention the ciliary glands, whose function is to secrete part, at least, of the aqueous humor; these are invaginations of the pigment epithelium into straight longitudinal tubular glands. The angle of the anterior chamber, at its posterior side, is bordered by the base of the ciliary muscle and ciliary body, but rounding out this angle are the fibres of the pectinate ligament, where its surface fibers face forward, which swing around this angle. The surface of this angle is covered over sparsely by the endothelium cells that line the cornea. The uveal tract is partly within the anterior chamber at this position, whereby we may have extension of pathological conditions.

The Iris (Rainbow).

The iris is attached to the ciliary body at about the center of its base, so that it is well away from the sclera at its periphery. It is interposed as a circular contractile curtain, dividing the anterior part of the eye into two unequal spaces, called the Anterior Chamber and the Posterior Chamber. This curtain, which glides over, but normally is not attached to, the front capsule of the lens, is pierced by a central opening called the Pupil. Through this pupillary opening is the passage for the aqueous humor, from the posterior to the anterior chamber. The anterior surface of the lens lies somewhat anterior to the posterior origin of the iris, so that the iris is somewhat forced forward at the pupillary border, thus making the iris conical in shape, with its apex forward. The pupil, up to the seventh month in the fœtus, is occluded by the so-called pupillary membrane, which is then absorbed, but infrequently may persist, wholly or in part, during life. When present, it gets its blood supply through its attachment to the iris.

The iris is the direct anterior continuation forward of the uveal tract, so that the Stroma Choroidea is the fundamental foundation of the iris makeup. It is covered anteriorly by the continuation backward of the endothelium of the cornea, and posteriorly by the epithelium of the retina, so that here we meet parts

of three distinct embryological developments, combining to form the iris tissue.

The iris has about the same diameter as the cornea (11 or 12 mm.). At its insertion it thins down quite perceptibly; from that point it thickens gradually up to its last fifth near the pupil, where it abruptly falls away to its rather angular pupillary margin. The posterior surface is flattened. The insertion of the iris in the ciliary body forms a movable union with that body; the angular character of the insertion causes the anterior wall to be longer than the posterior wall.

At its thickest portion the iris is under ordinary conditions, considered to be about 0.5 mm. thick. This varies, not only in different eyes, but also under different degrees of contraction or dilation of the pupil in the same eye. The pupil is displaced somewhat to the nasal side of the iris. While it is constantly changing in width, normally in adult life it is considered to be about 4 mm. in diameter. The size of the pupillary aperture determines the amount of light admitted into the eye. The iris, anteriorly, at its periphery, is attached to the sclera only through its connection with the fibres of the pectinate ligament, which swing around over, and are incorporated into, the iris tissue. When the walls of the iris are distended during dilation of the pupil, the anterior surface is the bulged surface, while the posterior surface retains its straight lines.

On examination of the iris in the living eye, we note certain concentric interrupted lines near the periphery; these are the contraction furrows, which, in conjunction with the inter-mingled crypts, allow the iris to be folded when dilated. Those furrows and crypts contain a variable amount of chromotophores and pigment in among the loose stroma. The crypts are seen throughout the whole anterior surface of the iris; the chromatophores are not only more frequent in the spaces of the crypts but cause a spotted appearance where they are collected in clumps, called clump cells. These are as irregularly placed as are freckles on the outer cuticle, and have the same significance from a pathologic standpoint, which is *nil*. In negroes and dark skinned people the deposits of these cells often materially interfere with the activity

of the iris muscle, and cause the iris to be more sluggish. The anterior surface of the iris is marked by radiating lines which diverge away from the pupil, and these lines are divided into two sections by the so-called pupillary ridge, an irregular zig-zag line at the junction of the outer one-fifth with the inner three-fifths of the iris, which marks the position of the minor arterial circle of the iris (circulus arteriosus iridis minor). The radiating lines of the inner or pupillary zone diverge away from the pupil, and are more delicate than those of the outer, or ciliary zone. These lines, in both zones, mark the paths of the vessels and the accompanying stroma of the iris.

The continuation of the stroma from the uveal tract into the iris, and the fact of the blood supply being identical, make possible metastasis of inflammations from one to the other.

The iris is composed of five layers called:

1. The Endothelial Layer.
2. The Stroma Propria.
3. The Muscular Coat.
4. The Posterior Limiting Membrane.
5. The Pigment Lining (or Pars Retinæ Iridis).

1. The Endothelial Layer of the Iris is the continuation of the lining endothelium of the cornea, which, when it passes on to the iris, is not well set off, and is difficult to demonstrate as a homogeneous layer, on account the lack of continuity and irregular mesh-like arrangement.

2. The Stroma Layer of the Iris consists of cells and fibres. The fibres are in delicate bundles, have a radial direction, generally away from the pupil, and accompany the blood vessels. In between the stroma are the crypts, which are more or less darkly pigmented. The depth of this pigment, which is very variable, determines the amount of light reflected from the posterior pigment layer of the iris; and this reflected light constitutes the color of the iris.

The vessels of the iris not only are intermingled with the stroma, but are accompanied by the nerve endings. These vessels follow the radial striations and are somewhat twisted upon themselves, so that they can easily be folded and unfolded. At the

ending of the ciliary zone they take a zig-zag, circular course, and there form a circle called the Minor Arterial Circle of the Iris (Circulus Arteriosus Iridis Minor). From there on, the vessels become smaller, and end in the capillary loops which bend around the pupillary margin. The veins return in about the same way.

The nerves of the iris are of three kinds, Sensory, Sympathetic, and Motor. These all end in the stroma layer, yet in the muscular layer some of the nerves have a definite individual termination.

3. The Muscular Coat of the Iris consists of two varieties of muscles, circular and radiating, both of which are involuntary muscles. The circular is the sphincter muscle of the iris and is set in among the stroma at the pupillary margin, in a narrow strip of 1 mm. wide. Like the other tissues of the iris, its fibres are not too closely packed together, so as to be capable of great contraction and expansion.

The radiating fibres of the muscular coat radiate away from the upper edge of the sphincter muscle, where they are incorporated with the looser sphincter fibres. These radiating fibres form the Dilator Pupillae muscle; at the periphery they bend over into the stroma of the ciliary body, and are lost among the vessels of the ciliary processes.

The loose separated bundles of the dilator pupillae muscle, by their contraction, assist in quickly emptying the aqueous from the crypts of the iris.

4. The Posterior Limiting Membrane, or Brueck's Membrane, is a continuation forward of the internal limiting membrane which covers the uveal tract throughout. While not so well marked here as in the ciliary body and choroid, it is the seating on which the pigmented coat lies.

5. The Pigment Lining is a continuation forward of the pigment coat of the ciliary body, which is now two layers in thickness, and, peculiar as it may seem, the connection between the two layers is less firm than the connection of the anterior coat with Bruck's Membrane, so that when this coat, by inflammation, becomes attached to the anterior surface of the lens, the layers will separate rather than both be pulled away from their iris con-

Vascular Circulation of Uvea

(1) Pupil. (2) Cornea. (3) Iris. (4) Position of major arterial circle. (5) Schlemm's canal. (6) Anterior ciliary artery and veins, showing anterior episcleral branch. (7) Long ciliary artery and nerve. (8) Sclera. (9) Vena vorticosa. (10) Short ciliary arteries and nerves. (11) Short ciliary arteries and nerves showing posterior episcleral branch. (12) Optic nerve sheath. (13) Long ciliary artery and nerve. (14) Vena vorticosa at sclera. (15) Anterior ciliary vessels. (16) Major arterial circle. (17) Minor arterial circle. (18) Posterior episcleral artery. (19) Anterior chamber.

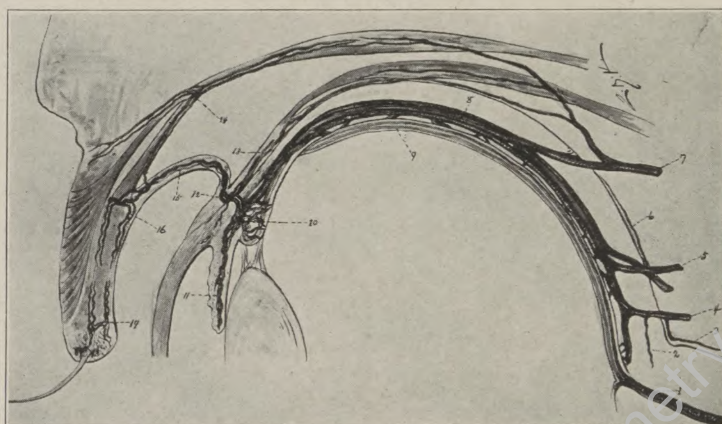
nection. When this lining reaches the iris border, it turns around that border, and may be seen as the more or less black margin of the pupil.

This pigmented lining is the coat which gives the color to the iris. When it can be seen through an unpigmented iris the iris appears blue; when much pigment intervenes, it appears black. In Albinoes not only is the iris stroma not pigmented, but the pigment lining has lost some of its intense black-brown pigment granules. This pigment layer is, from its source of origin, sometimes referred to as Pars Retinae Iridis. The color of the iris is nearly always proportioned to the general pigmentation of the rest of the body. In children the color of the eyes is blue at birth, because of the thinness of the stroma, and the absence of pigment deposits. The iris becomes thicker with age by the continued growth of the connective tissue and glass membrane structure, and the sluggish pupils of the aged may be partly accounted for in this way. The deposits of pigment may be uniform or irregular. When irregular, one eye is entirely or partly different in color from the other.

The blood supply of the uveal tract I have only partly touched upon, and then where it was necessary to explain a particular layer of the parts described. I will now try to show this supply as a completed system. The posterior arteries of the uvea are the short ciliary arteries which I described in conjunction with the description of the sclera. On their way forward they supply the choroid, and are chiefly distributed to the choroid and the external two layers of the retina. Their position is in among the medium-sized vessels of the choroid—and they end at about the ora serrata. The long ciliary arteries, without giving off any branches, run forward to about the middle of the base of the ciliary body, where they divide into two branches, forming a circle around the location of the iris insertion, which is called the Greater Circle of the Iris (Circulus Arteriosus Major Iridis). Now this circle has additional feeders from the anterior ciliary arteries, which pierce the sclera almost vertically, opposite the insertion of the ciliary muscle, and which pierce the ciliary muscle, giving off posterior branches into that muscle; they then empty into the circulus major iridis, which furnishes the radial arteries of the iris, and also gives off

posterior branches to the ciliary body and processes. The ciliary processes are really a massed or accumulated collection of arteries and uveal veins which freely anastimose.

The veins of the iris, ciliary body and choroid are all collected together to form the Vortices of the Choroid, with one exception, namely, the veins of the ciliary muscle, the venous blood of which



SCHEMATIC INTER OCULAR CIRCULATION.

(1) Central artery and vein. (2) Artery to assist in forming arterial circle of Zinn. (3) Artery to feed supra dural sheath of optic nerve. (4 and 5) Short ciliary arteries. (6) Branch to supply posterior episcleral space. (7) Vena vorticosa after receiving an external branch. (8) Veins of choroid. (9) Retinal vessels. (10) Arteria circulos majoris showing its anterior anastomosis and posterior supply. (11) Vessels of iris. (12) Anterior ciliary arteries and veins showing anastomosis from the various directions. (13) Anterior ciliary artery and veins in episcleral space. (14) Branches from the lacrymal artery and veins. (15) Anastomosis around fornix. (16 and 17) Superior and inferior vessel arch of upper lid.

is returned through the anterior ciliary veins, passing through the sclera near the uveal margin, receiving *en route* branches from the scleral tissue and from Schlemm's Canal. There is an anastomosis, however, between the anterior ciliary deep veins and the veins of the uveal tract, which are capable of expansion when called on for compensatory circulation.

The nerves of the uvea are the short ciliary nerves, which are branches of the ciliary ganglion, and the long ciliary which are

branches of the naso-ciliary branch of the fifth. The first form a plexus around the ciliary processes and iris, which sends non-medullated fibres into the sphincter and the Dilator Pupillae.

The fibres from the sympathetic plexus pass through the ciliary ganglion without forming a synapse in the ganglion, and supply the dilator pupillae, while the motor fibres that arise from the motor synapse, in the ciliary ganglion of the 3rd or oculo motor, supply the Sphincter Pupillae.

It is interesting to note that the (motor) third nerve supplies the sphincter pupillae, the ciliary muscle, and the internal rectus, so that the convergence of accommodation relies on the single excitation of this nerve nucleus.

The small amount of hemorrhage that occurs after operations or wounds of the iris, is because of the great and speedy contraction of its extremely sensitive muscular fibers.

CHAPTER III.

The Retina.

The Retina (the Seeing Brain) forms the inner coat of the eyeball—and is a positive forward extension of the brain, spread out over the inner surface of the eyeball, to receive the visual impressions of objects mediated by light waves. These impressions are conveyed by the same elemental extension to the intellectual centers, and placed in the storehouse of memory.

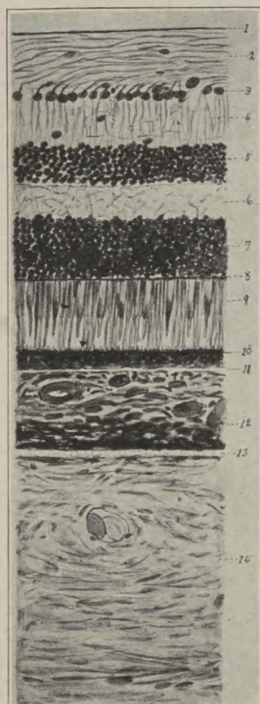
It is truly an expanded forebrain, the impressions of which necessarily must be transmitted to its final endings. The other structures described in this book are, in fact, all accessory to this one nerve element.

The retina in health in the living eye is perfectly transparent. When it is the subject of pathological conditions, however, it becomes opaque, or loses some of its transparency. On examination with an ophthalmoscope it appears a purplish red, due to the visual purple that is found in the outer ends of the Rods. On post-mortem examination the retina is a well-defined, thin, brittle, bleached, opaque membrane.

The retina is attached externally to the choroid, by its outer pigmented coat. Its inner surface is in contact with, but not attached to, the hyloid membrane of the vitreous body. Its nerve elements run as far forward as the posterior border of the ciliary body, where its serrated edge is known as the Ora Serrata. Its pigment coat advances forward to cover the ciliary body and the posterior plane of the iris, and is here known, respectively, as the Pars Ciliaris Retinae and the Pars Iridis Retinae.

In the posterior pole the retina is continuous with the optic nerve. On attempting to separate the retina from the choroid, we tear away all but the outer coat, which is more firmly attached to the choroid than to the coat to which it belongs, namely, the Retina. This coat is sometimes described as belonging to the choroid. Again, in the description of the coats of the retina, some authors omit the description of both the external and internal limiting membranes, so in various modern books the number of coats of the retina is variously given, as seven, eight, nine or ten.

As a matter of fact, the retina should be described, as we think of the brain, in neurons; of which, like the brain, the retina displays three synapses for its proper functioning, held together by the



SECTION OF RETINA, CHOROID AND SCLERA.

(1) Internal limiting membrane. (2) Nerve fiber layer. (3) Ganglionic layer. (4) Internal molecular layer. (5) Internal nuclear layer. (6) External molecular layer. (7) External nuclear layer. (8) External limiting membrane. (9) Layer rods and cones. (10) Retinal pigment layer and cilia. (11) Internal glass membrane of choroid. (12) Choroid showing outer pigment. (13) Supra choroid and lamina fusca. (14) Sclera.

supporting fibres of Muller. I will describe these neurons after I have taken up the separate layers.

The retina, at its connection with the optic nerve, at the entrance of the latter, measures about 0.4 mm. thick; it becomes

gradually thinner (to 0.1 mm.) toward its peripheral ending at the ora serrata. At a spot situated to the temporal side of the disk, about two disk-widths away, is a small depression where the retina becomes thinner, because several of its coats do not enter this area. It is called the Macula Lutea, and constitutes the optical center of the retina. In the center of the macula is a crypt called the Fovea Centralis, which has a central steep margin. On examination with an ophthalmoscope we get a different reflex from this spot than from the surrounding surface because of the depression with its central steep margin which reflects light differently from a plane surface.

The position of the exit of the optic nerve from the retina contains no visual elements, so that this space, being insensitive to light, is known as the blind spot; it is also called the optic disk, and measures about 1.5 mm. in diameter.

The retina is composed of ten layers of nerve tissue, bound together by a supporting skeletal network called Muller's fibres. The layers, from without inward, are:

(1) Pigment Layer.
(2) Rods and Cones.
(3) External Limiting Membrane.
(4) Outer Nuclear Layer.
(5) Outer Plexiform Layer.
(6) Inner Nuclear Layer.
(7) Inner Plexiform Layer.
(8) Ganglion Cell Layer.
(9) Nerve Fibre Layer.
(10) Internal Limiting Membrane.

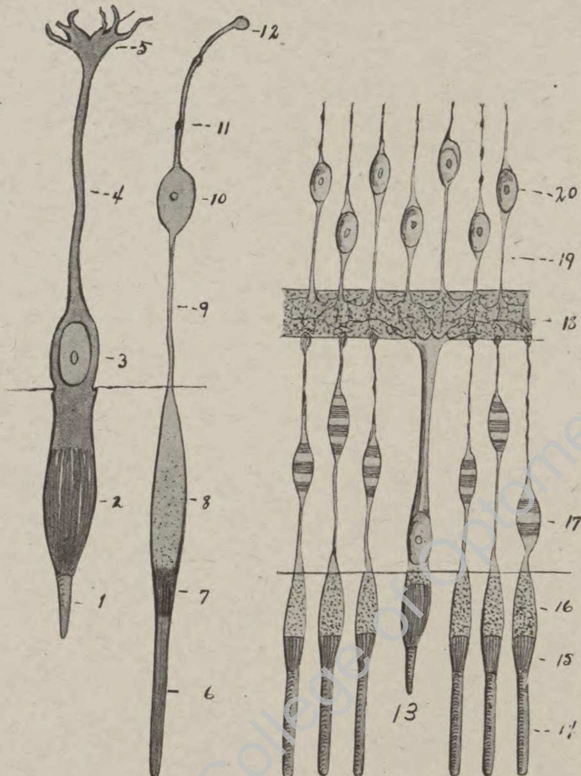
(1) The pigment layer of the retina is a single stratum of pigmented hexagonal epithelium cells. This layer belongs embryologically to the retina, and develops with the retina, although by many it is persistently described as belonging to the choroid, because, on post-mortem examination or in pathological conditions in life, the outer connection or seating on the internal limiting glass membrane of the choroid is firmer than the delicate connections

(not as yet demonstrated, although no doubt present) between it and the next layer of the retina, called the Rods and Cones. The cells of this layer are very uniformly pigmented, especially toward the inner surface, while the outer end contains the nucleus, which is less pigmented than the body of the cell. On the inner surface are developed minute long cilia-like processes, which intermingle with the rods and cones; these processes, when acted on by light, elongate and swell up between the rods and cones, thereby casting a shadow, as it were, on the delicate outer ends of the rods, to soften the intensity of the light impulse, which would otherwise be deleterious to the rods and cones. This is on the same principle that when mud is mixed with water it makes the water temporarily opaque. These cells are intensely pigmented, a chocolate brown as a rule. In albinoes the pigment is less, reducing the protection of the rods and cones, which might account for some of their generally poor vision. This is the retinal layer that extends forward to coat over the posterior surface of iris and the inner surface of the ciliary body and processes, where, as previously described, instead of a single layer of cells, it develops into a double layer.

(2) The layer of rods and cones affords the beginning nerve elements of perception, which, when stimulated by light, gather the picture vibrations to be converted into a mental impression. All the other layers are accessory to this elementary end of perception, so that any pathological changes in the other layers of the retina, or in the media through which the picture passes, will interfere with the functioning of this primary conversion apparatus. The rods are tubular, of nearly a uniform thickness, while the cones are shaped like a bottle with a narrow long neck. The neck-like processes or the narrower part of the rods and cones point outward, toward the inner surface of the pigment cells, where the rod-ends are lost among the ciliated pigment. The rods are much more numerous than the cones, in an estimated proportion of about 100 rods to 7 cones and 7 pigment cells (this refers to the pigment cells of the Nuclear Layer). In fact, the estimate has been carried further, giving the number of nerve fibres leaving the retina as about 500,000, each of which supplies

about 7 cones, 100 rods, and 7 pigment cells, so that there totals about 3,500,000 cones, 50,000,000 rods and 3,500,000 pigment cells in the retina (Brubaker's Physiology).

The rods are, therefore, more numerous in all parts of this coat, except in one place, namely, the macula, where they become



ROD AND CONE ELEMENTS

(Diagramatic.)

(1) Outer segment cone. (2) Inner segment (3) Cone nucleus. (4) Cone fiber. (5) Cone foot. (6) Outer segment rod. (7) Ellipsoid fibrillated portion (found in both fiber apparatus of some authors). (8) Inner segment rod. (9) Rod fiber. (10) Rod nucleus. (11) Rod nodules (Varicosities). (12) Knob ends. (13) Cone. (14) Outer segment rod. (15)-(16) Inner segment rod. (16) Outer nuclear layer. (18) Outer molecular layer. (19) Inner nuclear layer. (20) Bi-polar nucleus.

less numerous than the cones, while at the yellow spot or fovea centralis there are found only cones. Here these are crowded together, and the diameter approaches the extra-foveal diameter of the rods. The distance between the centers of two adjacent cones at the fovea is four micro-millimeters.

The rods are the length of the whole thickness of this layer, i. e., about 0.06 mm., and lie perpendicular to the surface of the coat. They are equally divided into two segments, an outer and an inner, which take on different stains and differ chemically thus acting toward light in a different manner. The outer segments in both rods and cones are doubly refracting, while the inner segments are singly refracting, in their action upon light.

The outer segment of the rods, seemingly an adjunct to the inner segment, is apparently composed of thin sheets vertical with the long axis. These are bound together by longitudinal fibres on the outer side of the segment, so that the disks are not easily demonstrated. This is the situation of the so-called Visual Purple (Rhodopsin), which can only be found in the rods. This visual purple is bleached by light, and reproduced in darkness. (In frogs some of the rods have a green color.)

The inner segment is granular in the center, with the long fibres of the outer segment continued into a thick network on its outer surface, which takes on a strongly refracting appearance.

The rods and cones are similar in structural make-up; their shape alone is different. The cones are, as stated, shaped like a bottle, with a slender and proportionately shorter neck, in fact a tapering end. Where the cones approach the macula they begin to be more slender, and taken on more of the general appearance of a rod, with the difference that in the macula, as in other regions, the outer segment does not contain any visual purple. Another interesting fact in connection with the cones is that, not only do they become less in number in proportion to the rods as they approach the ora serrata, but they become shorter and their diameter increases.

(3) The external limiting membrane is the outer supporting membrane of the retina; in fact, like the glial coat of the optic

nerve or the internal limiting membrane of the choroid, it is a spreading-out into a porous homogeneous layer of the fibres of Muller. In the meshes of the external limiting membrane are fixed the inner ends of the rods and cones. This membrane should be considered as much a definite layer as the glial coat of the optic nerve, because it serves a definite purpose and is anatomically demonstrable.

(4) The outer nuclear layer (or outer Granular Layer) is made up of cells with nuclei so large that the whole cell seems to be nucleus. There are, however, two kinds of cells in this layer, one called the Cone Granules and the other the Rod Granules, according as they are connected with a rod or cone. The cone granules are larger and lie nearer their respective cones; in fact, the base of the cones are in direct appositon, the fibres intermingling with the outer granular-tissue. Each granule sends a prolongation inward to synapse in the outer plexiform layer. The cone granule fibre is characterized by being thicker than the rod granule fibre, and also by ending in a heavy end, called the Cone Foot. In the fovea, however, this ending becomes thinner, and the fibre assumes nearly a horizontal course, rather than a vertical.

The rod granules are more numerous than the cone granules, lie further away, and have one single slender connecting fibre to each rod; internally the extension ends in a knob-like enlargement, to synapse in the outer plexiform layer; this internal fibre has numerous little swellings along its course. The rod granules are distinguished by having horizontal striations, and being situated farther away, or placed on the inner side of the outer nuclear layer.

At the outer periphery of the layer of rods and cones, where the outer narrow processes do not completely fill the space, there has been demonstrated, as normally present, a minute amount of lymph in these interspaces.

(5) The outer plexiform layer (or Inner Nuclear Layer), known by the older authors as the outer granular layer, is rather a difficult layer to describe, as it consists of end arborizations of the outer and inner nuclear layers, which arborizations in this

layer form the complicated separate varieties of synapsis, which we find in the retina, i. e., endings of arborizations approaching knobs, and baskets approaching arborizations. Intermingled in this layer, also, as in all the layers forward, are the sustentacular fibres of Muller, which, with the nerve endings, take a horizontal as well as a vertical course. This layer, however, is the site of the synapse between the outer neuron and the middle neuron, to which I will again refer.

(6) The inner nuclear layer is similar to the outer nuclear layer on minute examination, except, perhaps, the cells are packed closer together, so that the layer is perceptibly thinner than the outer nuclear layer.

These cells, for descriptive purposes, are divided into Bi-Polar, Horizontal, and Spongio-Blasts.

(a) The Bi-Polar cells are divided again into Rod Bi-Polars and Cone Bi-Polars, according as their outer processes are to synapse with a rod or a cone fibre. These constitute by far the greater number of cells of this layer. The inner poles or processes synapse with the ganglionic cells.

(b) The Horizontal cells lie next the outer border of this layer, but are again divided into an outer and an inner stratum, called outer and inner horizontal cells. Both have flattened horizontal processes which synapse with the elements of this layer laterally.

(c) The Spongio-Blasts, or Amocrine cells, are found along the inner border of this layer, and are divided into three types, the Stratified, the Desseminated, and the Association. These differ principally in the number and length of their processes all of which are generally directed in a horizontal direction.

(7) The inner plexiform layer or inner molecular layer has the same minute anatomical make-up as the outer plexiform layer, and is the place of synapsis of the middle with the inner neuron. On the outer side of this layer, or even among the elements of the inner nuclear layer, are found the capillaries of the central circulatory system of the retina.

(8) The gangion cell layer is a single stratum of trans-

parent nerve cells, except in the region of the macula, where they are superimposed on each other, while in the neighborhood of the wall of the fovea they may be six to eight layers deep. The dendrites of these cells synapse in the inner plexiform layer.

(9) The layer of nerve fibres forms the communicating connecting lines which convey the visual impressions from the retina to the brain, and are the spread-out endings of the optic nerve covering the inner surface of the eyeball. These endings are grouped to form a general radiating layer from the disk to the ora serrata. At the disk this layer is thicker than at the periphery, where it thins down very much, and is less than one-third as thick. The nerve fibres of this layer are non-medullated.

(10) The internal limiting membrane is, as the name indicates, the covering of the inner surface, lying next to the hyaloid membrane of the vitreous body. This, like the external limiting membrane, is a surface collection of the fibres of Müller, which here constitute a homogeneous membrane.

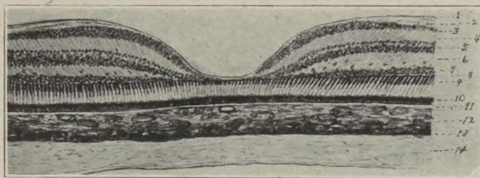
In the description of the retina I have mentioned the supporting fibres of Müller. These are, in fact, a supporting meshwork which not only penetrates vertically from its membranous endings, at the external and internal limiting membranes, but throughout the retina sends longitudinal fibres in among the nerve elements. The fibres of this supporting meshwork are of a true glial nature, having some cell nuclei which lie in among the internal nuclear cells.

The Macula Lutea.

The Macula Lutea and Fovea Centralis lie in the posterior direct visual axis of the eyeball, and constitute the point of most distinct vision. At the fovea, there are no rods and the other elements of the retina are mostly absent, so that at this variable depression (in all eyes it is extremely small) the retina is very thin, while the margin shows a thicker stratum of all fibres than at any other portion of the retina. The macula is about 2 mm. in diameter, and lies about 3 mm. away from the disk, toward the temporal side.

The varied steepness of the walls of the fovea accounts for

the different pictures presented of it when observed with an ophthalmoscope. The fovea measures about 0.5 mm. across, and is variously shaped. There is a gradual slope of the macular region toward the disk, in a vortical curve-like manner, on account of

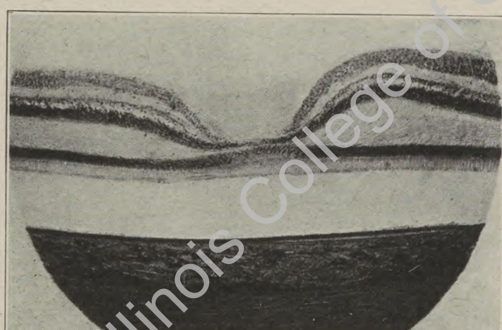


FOVEA CENTRALIS.

(1) Internal limiting membrane. (2) Nerve fibers. (3) Ganglionic cells. (4) Internal molecular layer. (5) Internal nuclear layer. (6) External molecular layer. (7) External nuclear layer. (8) External limiting membrane. (9) Rods and cones. (10) Retinal pigment layers showing cilia. (11) Internal limiting membrane of choroid. (12) Choroid showing pigment near outer edge. (13) Lamina fusca and supra choroidal space. (14) Sclera.

the nerve fibres falling away toward the disk on this side. The pigment layer of the retina and the pigment of the choroid seem more deeply colored at the fovea.

The ora serrata needs some further explanation. The visual elements of the retina all stop abruptly within a zone of 1 mm.



FOVEA CENTRALIS MICRO-PHOTOGRAPH.

The rods and cones are separated from the pigment coat by an artefact. Original from Fuchs' American Lecture, 1922.

from its edge, while on the temporal side the retina loses its visual power about 4 mm. back of the ora serrata.

The Blood Supply.

The blood vessels of the retina are quite distinct from the other blood vessels of the eyeball. The retina is supplied wholly by the central artery and vein, which enter the eye in the central portion of the optic disk, and on entering, break up into branches at the disk head, one branch of each going upward and one of each downward. These again and again divide, and are then named according to the direction taken, being known as the inferior and superior nasal, inferior and superior temporal, etc. All these vessels go toward the periphery of the retina, except that they carefully avoid the macula, whose center or yellow spot (fovea) is devoid of blood vessels. All the vessels, both arteries and veins, follow about the same course, and lie in among the nerve fibres underneath the internal limiting membrane. There is no anastomosis of the arteries and veins in their many branchings, but only through their capillary endings, and these capillaries do not make any collateral anastomosis with any other system of capillaries. Therefore, the retinal vessels are terminal vessels, and no compensation is possible when occlusion takes place in a vessel or section of vessels.

The outer layers of the retina, including the macula and fovea, not having any blood vessels, get their nutrition from the underlying capillaries of the choroid.

Some words as to the functional workings of the retina would be welcome, but outside of our knowledge that, on the introduction of light, the amœba-like pigmented cilia are stirred up along the visual purple of the apices of the rods and cones, we are without a solution to the problem.

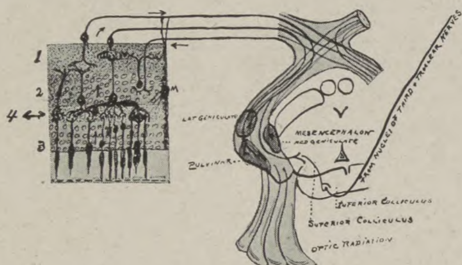
Neurons.

Neuron is the term applied to a nerve cell and all of its processes. The neuron theory, or doctrine, assumes that there is no continuity whatever between the substance of one neuron and that of another, but that the functional connection between them is brought about merely by the synapsis, or close approximation, of

the processes or dendrons of one element with the processes or dendrons, or the cell body itself, of another element. Synapsis means the intertwining of the dendron of a cell with the body or dendron of another; so neurons meet neurons by a synapse.

Neurons of the Retina.

Thus, with the above explanation of the neuron theory, and the showing of the synapsis in the outer and inner plexiform layers, we may readily see that the first neuron consists of the rods and cones and the nuclei, to which they are attached, the



SCHEMATIC DRAWING OF THE FOUR NEURONS OF THE RETINA.

(1) The ganglionic neuron with its nerve connections to the optic tract. (2) The bi-polar neuron. (3) The rods and cone neuron. (4) The horizontal neuron of the inner nuclear layer. The final ending of these neurons showing its intimate connection with the nuclei of the motor and sensory nerves of the eye, coincidently with the sensation being transmitted to the higher centers through the optic radiation.

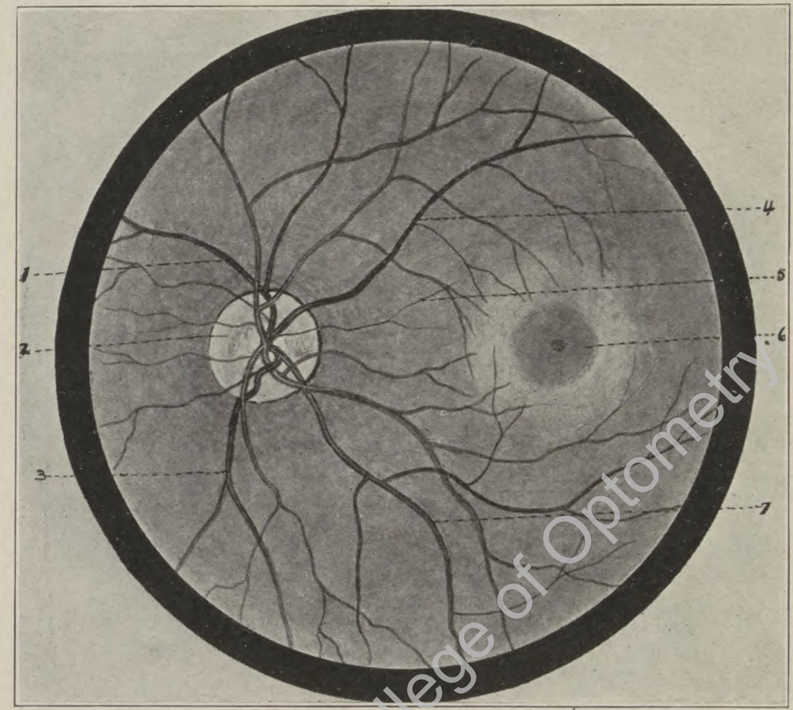
second, of the inner nuclear layer, and the third of the ganglion layer with the attending nerve fibres which are continuous to the brain, into the floor of the third ventricle.

Fundus.

The anatomical explanation of the various reflexes that are normal in the fundus is as follows: When the pigment epithelium layer of the retina is evenly opaque the choroidal stroma is in shadow, and the red blood of the choroidal vessels shows through this brownish tissue in a uniform manner—thereby giving us a uniform red reflex. When to this is added an intense pigmenta-

tion, such as occurs in the choroid stroma in brunette types, we have the darker red reflex which is characteristic of those types. The normal colors thus vary from a gray red to a brown red (in Chinese yellow red, in Negroes a dark slate red).

When there is a sparseness or absence of pigment granules



FUNDUS. RETINAL CIRCULATION.

(1) Superior nasal branch. (2) Disk. (3) Inferior nasal branch. (4) Superior temporal branch. (5) Superior macular branch. (6) Macula. (7) Inferior temporal. Note the choroidal and sclera rings at disk.

in this sperficial layer, then we observe the more intense chromatophore of the choroidal stroma in the interspaces between the vessel layers of the choroid, showing a mottled field, which appearance is called a tessillated fundus.

Again, if this sparseness of pigment extends into the choroidal stroma, with the blood vessels showing against the white sclera, it presents the characteristic albinotic fundus.

CHAPTER IV.

The Aqueous, Lens and Vitreous.

The interior of the eyeball, is occupied by three refractive media, called the Aqueous, Crystalline Lens, and the Vitreous Body (Humors of the older writers).

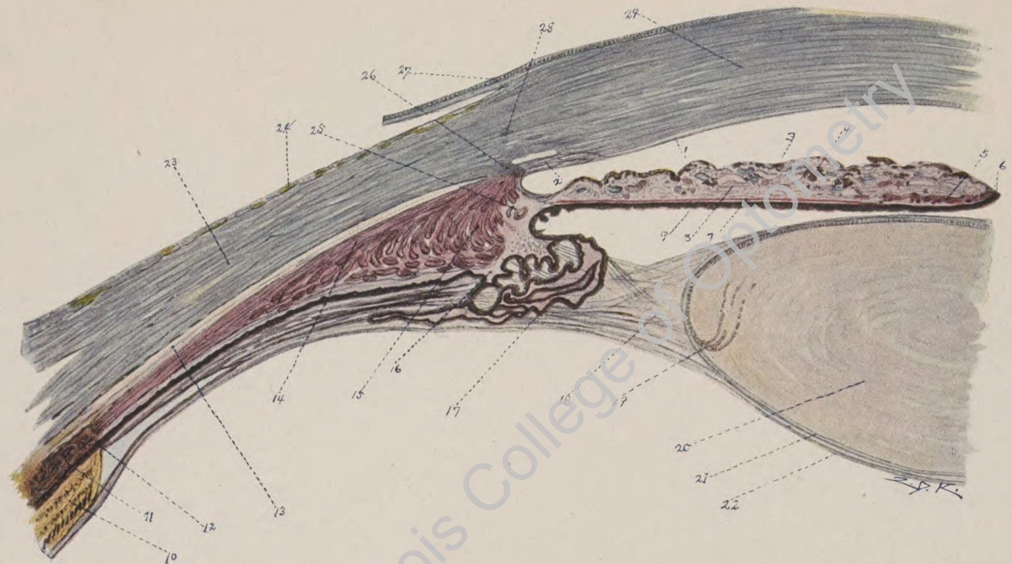
The Aqueous is contained in the anterior and posterior chambers of the eye, presently to be described. As its name implies, it is composed principally of water, with slight quantities of organic matter and inorganic salts in solution. It is colorless, slightly alkaline, has a specific gravity of 1.0025 and a refractive index of 1.333. It is a secretion of the glands in the ciliary processes and ciliary body. This secretion, during health, is constant, and is balanced by the outflow of aqueous through Schlemm's Canal. Any interference with these two processes of secretion and excretion of the aqueous is attended by a change in intraocular tension. The amount of aqueous normally present in the eye is from six to seven drops. By the ordinary process of secretion the entire aqueous content is renewed in about 50 to 60 minutes; in case of loss in evacuation of aqueous by puncture, however, it is replaced in approximately 7 minutes.

Any impairment of this and other media of the eye by pathological processes will cause more or less cloudiness in them, and so interfere with clear vision.

The Anterior Chamber.

The anterior chamber is situated immediately behind the cornea, and in front of the iris and of that portion of the capsule of the lens disclosed through the pupil. Its periphery is the angle occupied by the curving pectinate ligament. The greatest depth of the anterior chamber, measured from the anterior summit of the cornea to the anterior capsule of the exposed lens, is about 3.5 mm.

Old Physiologists called all bodily fluids humors, and these three were *incidentally* added to the four principal humors, namely, Blood, Phlegm, Choler or Yellow Bile, and Melancholy or Black Bile, all of which were considered a morbid fluid.



Angle of Uveal Tract and Anterior Chamber

(1) Descemets membrane. (2) Pectinate ligament with spaces of Fontana leading into canal of Schlemm, this "number" lies in the position of the so-called angle of the iris. (3) Anterior surface of iris showing crypts, with pigment granules irregularly placed. (4) Chromotophores or clump cells of pigment in stroma of iris. (5) Sphincter pupilli muscle. (6) Anterior border of pigment layer of iris. (7) Dilator pupilli muscle. (8) Stroma of iris. (9) Pars retinae irides, pigmentary coat. (10) Retina. (11) Choroid. (12) Position of ora serrata and beginning of orbicularis ciliaris. (13) Supra choroidal space. (14) Ciliary muscle, longitudinal fibers. (15) Ciliary muscle, circular fibers. (16) Ciliary body, ciliary stroma. (17) Ciliary processes covered with two coats of the pigment coat of the retina. (18) Suspensory ligaments of the lens with the interspaces, known as the canal of Petit. (19) The epithelium of the lens showing their transition of fibers carrying the lens nuclei away from the capsule. (20) Lens corticular substance. (21) Lens capsule. (22) Hyaloid capsule of vitreous. (23) Stroma of sclera. (24) Episcleral tissue. (25) Circulus arteria irides major. (26) Scleral roll. (27) Conjuctival layer. (28) Anterior ciliary veins. (29) Stroma propria of cornea.

The relations of the iris, at the periphery of the anterior chamber, as seen from the outer side, are important because of the many operations frequently done there. The iris lies about 1.5 mm. horizontally behind the limbus. At the pupil, however, it lies more forward than at the periphery; and this must be taken into consideration when making an incision, and in judging the depth of the anterior chamber.

The depth of the anterior chamber is altered, of course, by changes in the convexity of the cornea, and by any modification of the adjacent structures, such as the lens and the iris.

The Posterior Chamber.

The posterior chamber is much smaller than the anterior chamber; it connects with the anterior chamber through the pupillary opening. It lies behind the iris and in front of the anterior exposed surface of the hyaloid membrane of the vitreous. On its outer margin it is enclosed by the ciliary body and processes, while its inner border is the exposed parts of the periphery of the lens. This chamber is crossed by the interlacing suspensory ligaments of the lens, the open space between which is called the canal of Petit.

The Lens.

The crystalline lens lies in front of the vitreous body, its anterior surface forming part of the posterior wall of the anterior chamber. It is a bi-convex, colorless, transparent body, measuring, in the adult, 9 mm. in diameter, and about half that in thickness, and is enclosed in a capsule which is suspended by the suspensory ligaments. These ligaments are composed of many radiating fibres, which arise from the ciliary processes, and from the anterior elastic coat of the choroid, and are attached to the elastic capsule of the lens around the equator, some anterior, some posterior, and some between these two positions, at the equator. The irregular space, triangular in nature, which lies between these suspensory ligaments, is known as Petit's Canal.

The lens is more convex on its posterior aspect than in front, although, on account of its inherent elasticity, it is constantly changing shape during the process of accommodation, the anterior surface changing more than the posterior.

The equatorial edge of the lens is said not to be perfectly round, but indented; this, however, is much disputed.

The anterior surface has a radius of curvature of about 10 mm. while that of the posterior is about 6 mm. The refractive

LENS.

(1, 2 and 3) Showing relative shapes of lens from childhood to old age. (4) Lens showing lamellae and nucleus. (5) Posterior pole (polus posterior lentis). (6) Anterior pole (polus anterior lentis). (5 to 6) Axis (axis lentis). (7) Equator (aequator lentis). (8) Posterior surface (facies posterior lentis). (9) Anterior surface (facies anterior lentis). (10) Front view of lens.

power of the lens is about 25 D., its focal length about 55 mm. while the average refractive index of the outer and inner portions is about 1.40. This, however, is subject to variation. The specific gravity of the lens is 1.1, and it weighs about 0.25 gram (4 grains).

The insertions of the lens fibres are variable in direction and situation, and need some explanation. These insertions, as stated, are all around the equator of the lens, which equator, by the way, is further forward than posterior, on account of the greater convexity of the posterior surface throwing the equator forward, at least one-third more. So that the proportion of the situation would be, the junction of the anterior two-fifths to the posterior three-fifths. The insertions of the suspensory fibres are in addition 0.5 mm. more toward the front than toward the back, so that the the more numerous insertions are attached to the anterior capsule- The width of the insertion is about 2.5 mm. The insertion into the capsule is a gradual fading of one structureless glass membrane into the other, microscopically impossible to demonstrate as definite endings, although the entering lines are visible.

The Capsule of the Lens.

The lens capsule is an elastic glass membrane with the distinctive properties of glass membranes, namely: it has an elasticity that permits of being bent like a spring but not stretched; the structural composition can not be demonstrated, except by its peculiar affinity for particular stains; when injured it tends to roll away from the surface to which it is attached; it contains no vascular network which may be demonstrated; it becomes thicker in old age, and it is not affected by some chemical reagents, and certain inflammatory processes. All of these particular qualities are characteristic of the capsule of the lens. It is thicker in front of the lens than behind it in about the proportion of about 3 to 1 at the poles.

Before leaving the capsule, it is well to state that capsular cataract is not an opacity of the capsular substance, but opaque deposits on the capsule. Anterior capsular cataract is an opacity of the epithelium on the inner anterior surface of the capsule, while the posterior capsular cataract is a deposit on the outer posterior surface of the capsule.

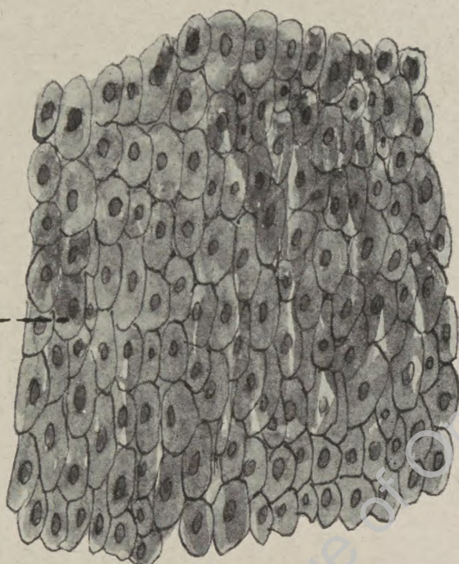
The Substance of the Lens.

There seems to be some confusion in the prevailing descriptions of the lens substance, due to the fact that certain anatomists

LENS CAPSULE AT EQUATOR, SURFACE ASPECT.

(1) Equator. (2) Posterior suspensory ligaments. (3) Periphery of epithelium. (4) Equitorial ligaments. (5) Anterior suspensory ligaments.

persist in regarding the anterior and peripheral portions as representing two separate cell groups. There is no sound reason for such a view. Epithelium is well understood to develop by proliferation, or the splitting of one cell and nucleus into two parts, which then develop into two complete cells while lying in close apposition to each other, and this is unquestionably the process which characterizes the development of the lens substance, the peripheral cells being forced further toward the equator and

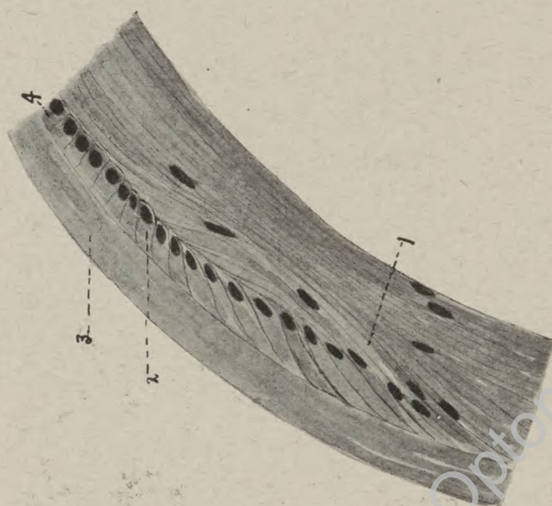


Central superficial surface view of anterior lens epithelium, showing its crowded condition.

taking on an elongated shape. The precise rationale of this process is inexplicable, but this does not change the fact that the peripheral structure is embryologically and developmentally identical with the anterior structure, and we shall consider them as one.

The epithelium of the lens develops as a single layer of cells under the surface of the anterior capsule; there is no distinctive cell layer on the posterior (capsular) inner surface.

These cells are columnar epithelium, with irregular angular facets on the sides, the front and back surfaces being flattened. Toward the centre of the anterior surface of the capsule they are crowded together, while at the periphery they take on a more regular form, and, instead of being placed in an apparently haphazard manner, are arranged in regular rows, become lengthened out, and finally arrange themselves in an angular manner, with



CROSS SECTION OF LENS NEAR PERIPHERY.

(1) Lens epithelial fibers as they become lengthened out, carrying nucleus away from their original position. (2) Lens epithelium taking an angular position at periphery of anterior surface. (3) Anterior capsule. (4) Lens epithelium taking on a regular shape somewhat further toward center.

the body of the cell on either side stretching out. In this way the nucleus is thrown further away from the surface, the nucleus in one cell lying a little more inward in relation to the one above it, so as to make a regular linear curve toward the centre. The cells are hexagonal, and maintain that general shape in their infoldings.

The cells do not intermingle, but lie in rows, layer upon layer,

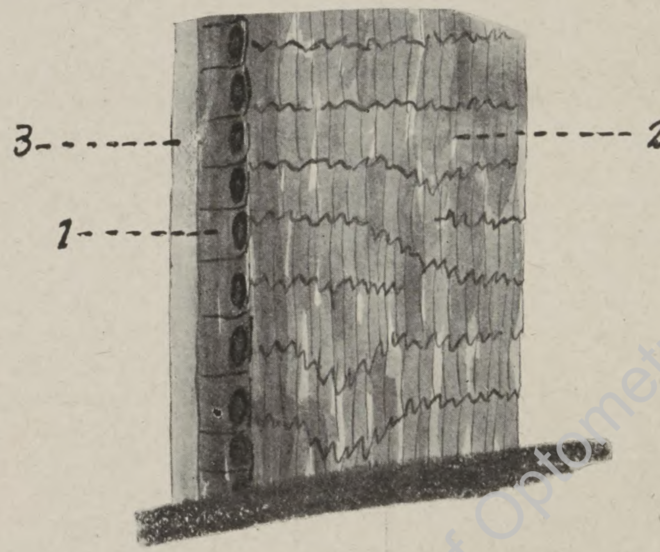
like the layers of an onion, and keep that laminated arrangement into the centre of the lens, which is called the nucleus. [We have spoken above of the nucleus cells.]

This lens growth is of epithelial origin, and if on the surface, it would grow from the bottom up, and undergo exfoliation on the superfacies; but the lens exfoliates toward the centre, where the older cells are packed more and more tightly during life; they even lose their nucleus before arriving at the centre, and as old age approaches the nucleus of the lens becomes more yellow and opaque from the concentration of the natural yellow tinge of the lens substance. The growth of the lens occurs like other epithelial growth, i. e., new cells are grown out of the splitting of the primary cells, and are set next to them; they then advance toward the periphery to take the position of those which have been crowded toward the nucleus of the lens. This process going on from all sides, the fibres are concentrically assembled, so that there appear, as in the sections of an orange, radial stripes along the growth of the fibres, as these start from the front and end at the posterior capsule. There is thus formed a Y-shaped configuration, each line of the Y meeting at an angle of about 120 degrees; or, better, a star-shaped configuration of about a dozen partially intersecting main lines (in children three lines are easily observed, showing an inverted "Y" anteriorly, and an upright "Y" posteriorly).

Along these stellate lines are first noticed the beginning of cortical cataracts. It being true that the normal function of epithelium throughout the body is to continue to grow and furnish replacements during life, the same holds good of the lens, and while the nucleus attempts to provide for this constant growth, yet it is not adequate to entirely assimilate the new growth, so that the lens, from the age of twenty-five to sixty-five years, becomes about one-third larger in diameter, (some say in width also), and one-third heavier. This, while normal, may be of pathological importance. In children the lens is rounder than in adults, while in the aged it becomes flatter and less elastic. In the foetus it is of a reddish hue.

The concentration of the yellow nucleus in the aged, above referred to, sometimes affects their color perception, especially for blue.

The hardening of the nucleus is further advanced in some individuals than in others at the same age. It is estimated that there are about 2250 lamellae in the lens; when lenticular cataract



LENS CROSS SECTION SHOWING LAMELLAE.
(1) Lens epithelun. (2) Lamellae, cross section. (3) Anterior capsule.

occurs there is generally a collection of liquid in spherical drops between the lamellae which soon become cloudy, and develop a fatty mass, called "Spheres of Morgagni," which may eventually coalesce into a larger mass.

Nuclear cataracts are an intense hardening of the nucleus, which becomes opaque and remains unchanged in situ.

There are no vessels in the lens; it gets its nourishment, by osmosis, from the ciliary processes around the insertions of the suspensory ligaments.

The Vitreous.

The Vitreous Body occupies about four-fifths of the cavity of the eyeball. It is partially surrounded by the retina, and is bordered anteriorly by the lens, the vitreous filling up this whole space; anteriorly, where the lens is situated, the vitreous shows a concavity, called the Della, or Fossa Patellaris.

The vitreous has a hyaloid capsular covering, which sends filaments to form an interstitial meshwork interwoven throughout the whole vitreous body.

The vitreous, therefore, consists of a multiple capsule filled with fluid giving it a jelly-like consistency.

The vitreous capsule is attached to the disk by the remaining fibres of the hyaloid canal, (which in a foetus up to the sixth month, gives passage to the hyaloid vessels, these vessels afterward disappearing) and it is also attached to the 2 mm. zone of the orbicularis ciliaris at the ora serrata. These two attachments are so firm that when they are forcibly broken the capsule of the vitreous will be found to have clinging to it some of the adjacent retina and ciliary body. The regularity of the laminated structure of the inner fibres of the interwoven vitreous membrane is perhaps best demonstrated after a rupture of blood vessels or pus into the vitreous body, when the cells making up this effusion can be seen in regularly arranged rows, one cell exactly following the other. If no such fixed structure were present, the blood corpuscles would naturally be a conglomerated mass. I mention this because, up to now, we cannot definitely show this interweave in a normal vitreous with any instrument we have at hand. It is possible that our technique is at fault. That there is considerable material to the hyaloid membrane is shown by the fact that it can be weighed, when the water is filtered out, and that at its places of attachment, and to some extent on the entire surface, the fibres can be made out quite distinctly. Some cells are quoted as demonstrable in the vitreous, which Fuchs thinks, are "emigrated leucocytes."

The interstitial membrane of the vitreous seems to have considerable strength, and, like a spider's web, not in the individual

fiber but in the association of all the weak fibres, makes a strong structure, which remains firm a long time after death.

The fluid of the vitreous resembles the aqueous, but is somewhat more alkaline, and has a specific gravity of 1.005. The fluid represents 98.5% of the whole vitreous body. The index of refraction is the same as that of the aqueous, namely 1.333. After birth the vitreous has no blood vessels of its own, but gets its nourishment from the ciliary body, so that any pathological disturbance of the inner coats of the eye will interfere with the nourishment of the vitreous.

Lymph Passages of the Eye.

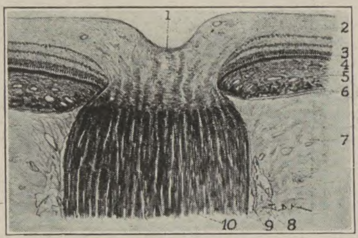
There are no lymphatic vessels in the eyeball, but there are some passages containing lymph, besides the spaces containing the aqueous and the vitreous liquid, which, on account of their non-coagulability, are hardly to be considered lymph, but rather secretions to re-enter the circulation immediately without alteration.

The lymph passages are: the supra-choroidal space, which we have described, the supra- or episcleral space, which latter is continuous around the whole interorbital-Tenon's-capsular space; the space between the rods and cones and the pigmented epithelium of the retina; and the inter-vaginal spaces of the optic nerve.

CHAPTER V.

The Optic Nerve.

The Optic Nerve (Nervus Opticus) consists of a group of nerve fibers, directed away from the anterior ganglionic cell layer of the retina, proceeding toward the optic disk, where they are assembled in bundles, to pierce the cribriform plate, thus



OPTIC NERVE HEAD.

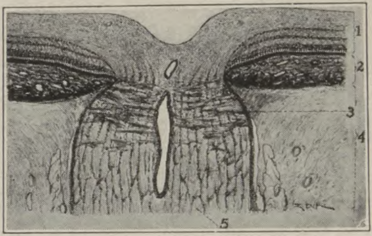
Weigert's stain of the neural sheaths which especially take this stain. (1) Physiological excavation. (2) Nerve fibers from retina to optic disk (3) Rods and cones. (4) Pigment coat retina. (5) Sclera showing pigment in outer layer. (6) Lamina fusca and supra choroidal space. (7) Sclera. (8) Inter vaginal space (supra arachnoid space). (9) Supra pial space. (10) Nural sheaths.

forming the optic nerve, which finally reaches the cranial cavity through the foramen opticum. The part within the eyeball is known as the intra-ocular portion; outside the cribriform plate as far as the foramen opticum is the intra-orbital portion; that contained in the cranium is the intra-cranial portion.

Micro-photograph Weigert's stain, showing nerve fiber sheaths. Original from Fuchs' American Lecture Series.

The intra-ocular portion of the optic nerve consists of non-medullated fibers, which are extensions of the ganglion cells, and

are perfectly transparent. They take on a whorl-like twist as they approach the posterior pole of the eye, where, on account of their number increasing from before backward, the retina becomes



Longitudinal section of optic disk. Showing physiological cupping and openings of central vessels. (1) Retina. (2) Choroid. (3) Transverse lamina cribrosa. (4) Sclera. (5) Nerve bundles.

distinctly thicker. At the optic disk, which marks the nerve's exit, these fibers form a bulge forward as they dip over the sides of this opening, which is named the Papilla Nervi Optici (Optic Disk). This is the inner side of the cribriform plate (lamina cribrosa). In the center of the papilla, or the center of

Micro-photograph of optic nerve, showing an artefact of the retinal separation of the rod and cone layer from the retinal pigment layer, also a separation of the choroid from the sclera. The inter vaginal space is well illustrated. Original from Fuchs' American Lecture Series.

the whorl of fibers at this point, is a depression, or funnel, which naturally occurs as the fibers seek a concentric formation. This funnel-like depression, which is of various forms, some more conical than others, is called the Physiological Excavation or cup. In the center of the funnel is the opening for the transmission of

the central vessels of the optic nerve (Arteria et Venae Centrales Retinae). These vessels make a right-angle turn at the so-called summit of the papilla, both having similar directions, whether you refer to the emergence of the veins or the entrance of the artery. Perhaps they are held here by the hyaloid remains of the hyaloid vessels. Just what supporting fibers hold them in place is not definitely determined, but that they lie above the nerve fibers at the disk seems plain.

All the layers of the retina end at the edge of the papilla; in fact, they thin away into a wedge, so that the outer layer of rods and cones and the pigment layer, seen on cross-section, form the sharp point of the wedge.

The fact that more nerve fibers go into the disk from the nasal than from the temporal side, and that the retina is somewhat flattened out toward the macula on the temporal side, causes the physiologic excavation to be somewhat shifted toward the temporal side of the papilla.

The Papilla is, in a general form, rounded, but may be slightly oval, with the long axis vertical. It is about 3 mm. to the nasal side of the optical center of the eyeball, and 1 mm. below the equatorial axis. It measures about 1.5 mm. in diameter and is quite uniform in size in *all* individuals. The physiologic excavation, however, is very variable, both in its axis direction and its form, so that, on observing the disk, the picture presented will greatly depend on the shape of the excavation, and the angle taken by the nerve in relation to its scleral egress, which is designated the axis of the nerve.

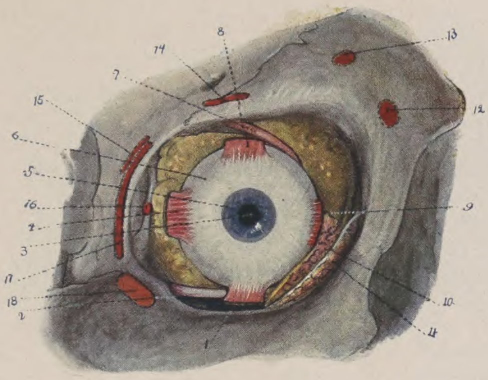
The optic nerve, in perforating the lamina cribrosa, must first pierce the choroid coat, which here thins down to elastic tissue and pigment, the pigment causing a grey appearance of the disk, in contrast to the red appearance of the surrounding retina. The termination of the black pigmented margin shows as a black ring around the disk, which ring may be complete, or broken, or appearing all on one side or another. This is called the choroidal ring. The nerve fibers then pierce the transverse fibers of the sclera, which form the greater thickness of the lamina cribrosa; there is a white ring of these fibers showing just within the black

ring, called the scleral ring; this ring, like the choroidal ring, is subject to variations in width and completeness. In particular, if the nerve canal is bent at an acute angle, or deviates from a vertical axis, the scleral ring will show as a white crescent opposite the side of the deviation.

The lamina cribrosa is about 0.5 mm. thick, and is normally somewhat concave, with the concavity facing inward. The inner surface of the optic disk is the narrow diameter of the scleral canal, while the outer end is widened, so that the nerve at the outer bulbar exit, will measure about 3 mm. in diameter.

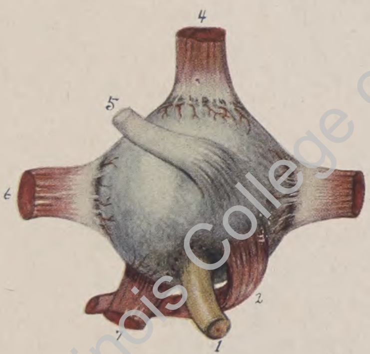
The transverse fibers of the choroid and sclera turn backward and form a union with the glial coating of the medullated fibers, whose medullations begin at the cribriform plate. The blood vessels of the circle of Zinn penetrate into the cribriform plate, to anastomose, in the interspaces (Septa) of the nerve fiber bundles, with the vessels supplying these interspaces. These latter vessels are from the central vessels of the optic nerve, and are given off posteriorly. Most of the sclera turns back at the cribriform plate; in fact the fibers it sends across to form the plate are only about one-third of the scleral thickness, while two-thirds are reflected back to form the outer coats of the optic nerve. These coats increase the diameter of the nerve from about 3 mm. to 5 mm. and this diameter is maintained as far as the orbital entrance of the foramen opticum. From the bulb to the optic foramen, the optic nerve measures about 26 mm. in length, which is a greater distance than a straight line joining these two points, so that the nerve is somewhat bent, in the shape of the letter "S" and is freely movable to accommodate the various movements of the eye. This is made necessary by the fact that the center of rotation is somewhat behind the equator. This posterior field of movement is almost as great as the field over which the corneal apex travels in its movement. For that reason I believe the center of rotation should be placed somewhat back of the usually designated plane of rotation, which is said to be about 10 mm. in front of the macula.

The turned-back outer sheath of the sclera becomes continuous with the dural sheath of the optic nerve, and is continuous



Anterior View with Muscular Connections in and Around Orbit

(1) M. superior rectus. (2) Tendon m. superior oblique. (3) Pupil. (4) M. medial rectus. (5) Iris. (6) Sclera. (7) M. inferior oblique. (8) M. inferior rectus. (9) M. lateral rectus. (10) Lateral horn of m. levator palpebrae superior. (11) Lacrimal gland showing the two lobes. (12) & (13) Origin zygomaticus muscle. (14) Origin infra-orbital muscle. (15) Origin levator anguli orris muscle. (16) Insertion pars m. lacrimalis (Horner's muscle). (17) Origin orbicularis oculi muscle. (18) Origin corrugator supercilii muscle.



The Eye-Ball From the Rear

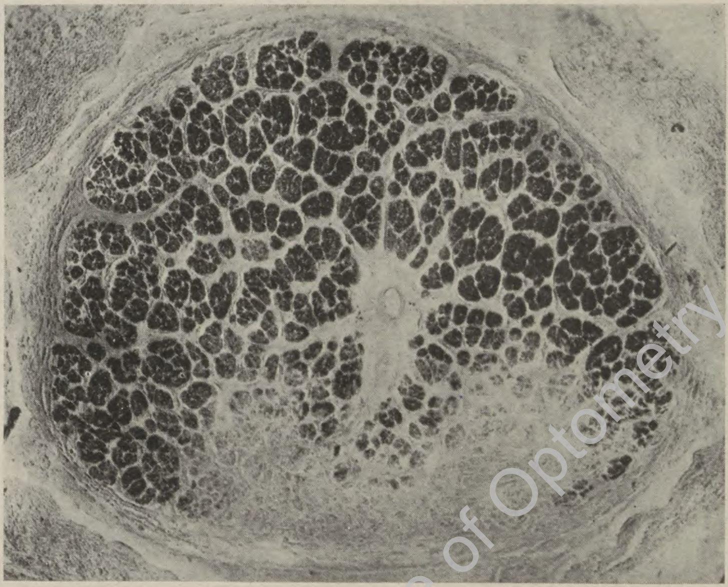
Showing the insertions of the muscles and their relations to each other and to the optic nerve, also some secondary insertions are indicated. (1) Optic nerve. (2) Inferior oblique. (3) External rectus. (4) Superior rectus. (5) Superior oblique. (6) Internal rectus. (7) Inferior rectus.

through the foramen opticum with the dural sheath of the brain. At the outer boundary of the cribriform plate, the sclera which forms the outer coating of the optic nerve splits into two segments, the inner segment becoming continuous with the arachnoid sheath of the optic nerve and remaining continuous with it into the cranial cavity. The space between these two split portions, (or, as they are now known, the dura and arachnoid membrane), and the space above the pial sheath, are known as the intra-vaginal spaces, also called the sub-dural and sub-arachnoid spaces. These are lymph channels which are continuous with the intra-cranial spaces of the sheaths. They are in reality potential spaces, and are crossed by fibrillae from one sheath to another. These spaces are lined by endothelial cells which are continuous with those of the cerebral space. There is a similar fibrillar connective tissue arrangement between the arachnoid and the pial sheath of the nerve itself, with, perhaps, greater increase of connecting fibrillae than between the dural and the arachnoid sheaths.

There is an additional covering of the optic nerve, constructed by the reflection of Tenon's capsule over its outer surface. The space between the nerve and the capsule is known as the supra-vaginal space, in which are the vessels and nerves that supply the sheath of the nerve. These vessels, anteriorly, are the reflections backward of supra-scleral branches of the short ciliary arteries, before they enter the sclera. The vascular ring of the sclera (vascular circle of Zinn) consists of branches within the sclera of the same short ciliary arteries.

The medullated portion of the optic nerve is that collection of nerve fibres which, having pierced the lamina cribrosa in bundles, take on the coating of the connective tissue stroma of the choroid and sclera, which these coverings meet outside the lamina cribrosa. These glial fibers are continuous forward from the intra-cranial portion of the nerve, in which latter situation they are the sole coating of the optic nerve. These coatings not only cover the outer side of the bundles of nerve fibers, but they send branches into the intervals between the nerve fibers, which are the components of the individual bundle. These fibers do not form in-

dividual sheaths for each strand of the nerve fibers, but constitute an interwoven meshwork of fibrillae, which serves to separate these bundles completely like a mesh-like covering. In the interspaces the inter-communicating arteries and veins and their complex system of capillaries are allowed to course. These strands of optic nerve fibers are about 800 in number, and are quite irregularly rounded on transverse section.



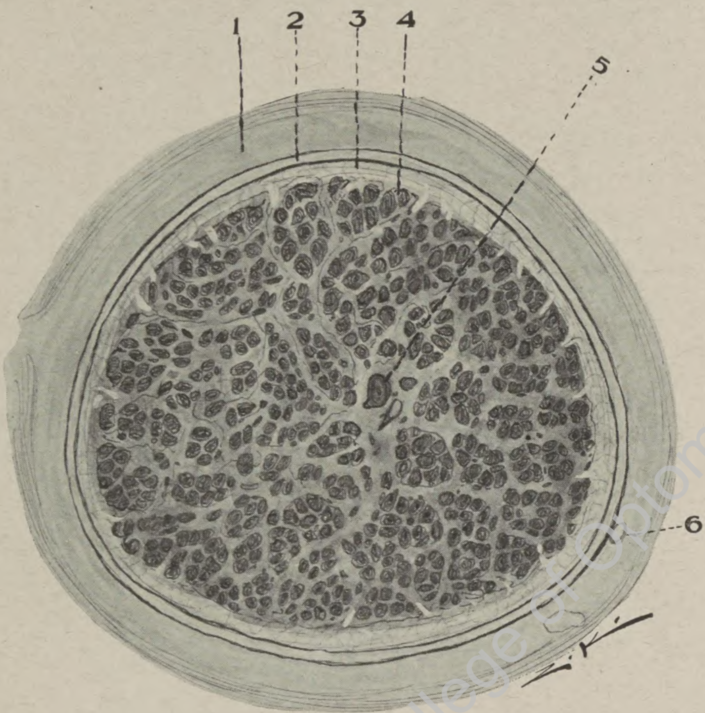
MICRO PHOTOGRAPH OF CROSS SECTION OPTIC NERVE.

Lighter portion shows an atrophy of portion of nerve; the rest, however, is normal. Original from Fuchs' American Lectures.

The intercepting septa, on arriving at the periphery of the nerve, are so connected that a well-marked thickened layer, continuous around the nerve, is formed; this constitutes the pial sheath of the optic nerve, which sheath continues into the cranial cavity. There is a marked increase in the size of the optic nerve at its exit from the scleral canal, and also a marked diminution at its entrance into the foramen opticum, which, on account of the

unyielding nature of these two canals, assume a pathological importance in inflammations of the optic nerve.

Perhaps it is well to state that the pial sheath is lost at the cribriform plate by its interlacing into the reflected fibers of the sclero-choroidal tissues of that plate.



CROSS SECTION OPTIC NERVE.

(1) Dural sheath. (2) Arachnoid sheath. (3) Pial sheath. (4) Nerve fibers. (5) Central vessels. (6) Vessels in dural sheath.

In protrusion of the eyeball (Exopthalmus) the mobility of the globe is much interfered with, on account of the stretching of the optic nerve, which limits the excursion of the posterior pole. The restriction is in direct proportion to the protrusion.

The thinness of the lamina cribrosa, and its loose mesh-like character, make this the weakest portion of the external tunics of the eye, and a marked increase in intra-ocular pressure causes this place to recede, so as to form a noticeable excavation, (Pathologic Cup).

CHAPTER VI.

Orbitae.

The Fossae Orbitales, (The Orbital Cavities, Orbits), are two irregularly-shaped pyramidal cavities, situated on the superior and lateral aspect of the skull. The open bases of these fossae (Aditus Orbitae) are directed forward, while the apices lie posteriorly, at the middle of the entrance of the foramina optica; the distance from base to apex, "is about 42.5 mm." The form of the fossae orbitales forward is that of a four-surfaced pyramid, while posteriorly, where the paries inferior (inferior wall), assumes the same plane as the paries medialis (medial wall), the pyramid becomes three-surfaced.

The Paries Mediales (Medial walls, Nasal walls) are nearly parallel, while the Paries Lateralis converge toward the Paries Mediales at an angle of about 45 degrees, so that if the two lateral walls were continued backward they would meet, forming an angle of 90 degrees, and this meeting place would be about 20 mm. back of the anterior opening of the foramen opticum, at the middle of the sella turcica.

The Paries Superior (Superior wall) is generally horizontal, and parallel with the Paries Inferior, although the latter may be said to be directed upward at its posterior aspect.

The irregularity of the surfaces, and their relational position as regards each other, makes the description of the Paries orbitalis, an empiric, rather than a true anatomic, one.

The contour and dimensions of the aditus orbitae (Orbital Entrance or Base) not only change during life, but differ markedly in individuals of the same race. However, there are some characteristic manifestations which distinguish individuals of the same race; there is also a racial distinctiveness which is generally characteristic of that particular race.

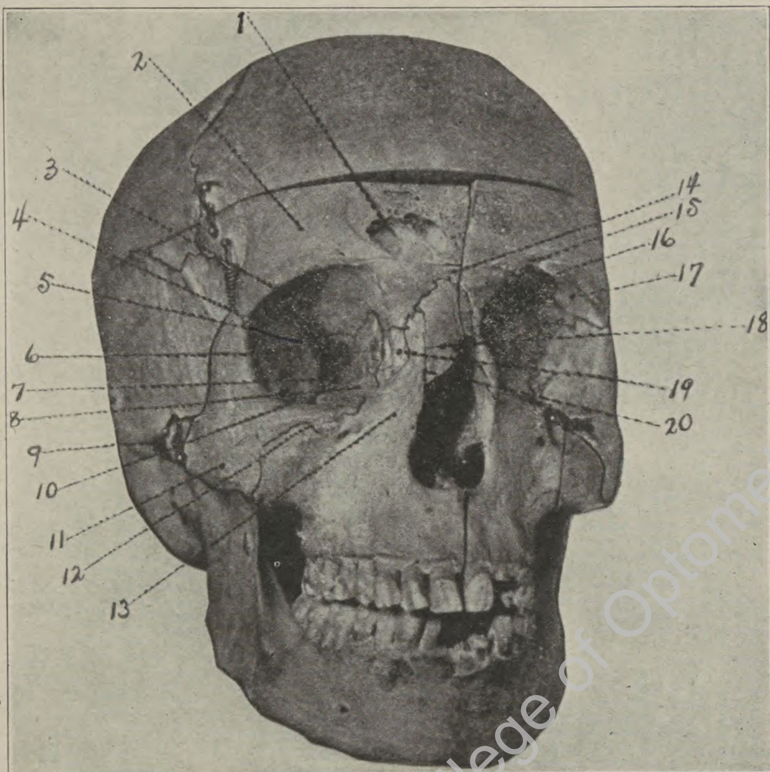
The cubic area of the fossa orbitalis in adults is about 30 cc. while in children it is about 20 cc. The aditus orbitae is more or less like the anterior portion of the fossa orbitalis, quadrangular and surmounted by a ridge with rounded corners. This ridge is known as the Margo Orbitae and is again arbitrarily divided for

descriptive purposes into four sections known as the margo supra-orbitalis, infra-orbitalis, lateralis-orbitalis, and medialis-orbitalis.

The height of the fossa orbitalis is about 35 mm. taken at the margo orbitae, while the width, at the same place, is about 40 mm. These two measurements need some explanation, as the average heights have varied quite as much as the widths. The height has been variously noted by different authors as from 31 to 40 mm. (e. g. by such authors as LaGrange, Flower, Arlt and others), but it remains about 35 mm. more uniformly than any other given dimensions. This dimension is generally proportionately higher in the female. Just within the cavity, behind the margo orbitae, the height suddenly increases about 3 to 5 mm. The width of the aditus orbitae, or opening, is subject to many variations and has been noted by such men as Emmet, Weiss, Merkel and others, to vary from 37 to 46 mm. The reason of the variation is that one measures from the tubercle zygomaticum to the anterior margin of the fossa sacci lacrimalis, while another measures to the posterior margin of the same, making a difference of about 3 to 4 mm. on the start. Another reason is the inexact point of the beginning of the measurement. One measurement also seems too small, that is the measurement of the distance I have given for the wall distance away from the eyeball, but it must be remembered that the wall distance of the width at the equator is some 12 mm. back of the aditus orbitae (base). This measurement is often confounded with the distance from the canthi to the limbus.

The Margo Lateralis-Orbitalis (lateralward margin) is placed so far back of the margo medialis-orbitalis (medialward margin) that if a line were drawn through the two lateralward margins of either side, directly through the eyeballs, this line would bisect the eyeballs back of their equators; which means that the lateralward margins are more than 13 mm. posterior to the anterior planes of the medialward margins.

If a vertical line, under normal conditions, were drawn from the center of the margo supra-orbitalis (superior margin), to the margo infra-orbitalis, with the eyelids closed, this line would rest on the apex of the cornea.



AMERICAN SKULL.

(1) Frontal sinus. (2) Superciliary ridge. (3) Orbit plate frontal bone. (4) Zygomatic frontal suture. (5) Greater wing sphenoid. (6) Foramen opticum. (7) Superior orbital fissure. (8) Lamina papyracea of ethmoid bone. (9) External auditory meatus. (10) Inferior orbital margin. (11) Malar bone. (12) Zygomatic-maxillary suture. (13) Maxilla. (14) Glabella. (15) Supra orbital notch. (16) Supra orbital margin. (17) Fossa lacrimal gland. (18) Nasal bone. (19) Lacrimal bone. (20) Maxillo-nasal suture.

The general long axis of the orbits in adults is depressed forward from the horizontal about 20 degrees. At birth the orbits are almost perfectly rounded, because they are moulded around previously shaped eyeballs, while the later development, and subsequent additions and growth of the adnexia, change the configuration of these cavities very materially.

The base (aditus orbitae) is then directed downward and lateralward, and around the base develops the thickened ridge known as the margo orbitae (orbital margin) ; just inside this ridge the orbitae are somewhat larger.

At the apex of each orbit is the Foramen Opticum (Optic Canal, Canalis Nervi Optici). This is recognized as the apical end of the orbits, however, it must naturally yield some of its claims to the Fissura Supra-Orbitalis (Superior Orbital Fissure, Sphenoidal Fissure). The inferior and wider portion of this fissure lies in the same plane with the foramen opticum; and the tendon of Zinn (ligamentum Zinn) attachment, around these two spaces, which on the medial side is the anterior edge of the optic foramen, would perhaps be the better situation to mark the apical position, as it is more definite than simply saying the optic foramen.

The foramen opticum is an opening in the interval between the two roots of the alae parvae ossis sphenoidalis (lesser wings of the sphenoid bone), and measures about 5 or 6 mm. in diameter; it is rather oval at its orbital entrance. The general axis of this canal is at an angle of 45 degrees forward from a sagittal plane, so that the nervus opticus, on its first entrance into the orbit, makes a curve of 23 degrees at this orbital entrance of the canalis opticus.

The Fissura Superior Orbitalis (Superior Orbital Fissue, Sphenoidal Fissure), measuring about 18 mm. long, is the opening between the Ala Parva and Ala Magna Ossis Sphenoidalis—(Lesser and Greater Wings of the Sphenoidal Bone). By its superior lateralward extension, it divides the lateral wall (paries lateralis) from the superior wall (paries superior), while its quadrangular portion medialward forms a part of the apex proper

of the orbit. The fissura superior orbitalis is the route through which the following vessels and nerves enter or leave the orbit, namely:

(1) The venae ophthalmicae (superior and inferior). (The opthalmic veins, superior and inferior branches).

(2) The nervus oculomotoris (third nerve).

(3) Nervus trochlearis (fourth nerve).

(4) Nervus opthalmicus (opthalmic division of the fifth, known as nervus trigeminus or trifacialis) this in three divisions (a) Nasalis, (b) Lacrimalis, (c) Frontalis.

(5) The sympathetic root of the ciliary ganglion.

The Fissura Orbitalis Inferior (Spheno-maxillary fissure, inferior orbital fissure) is continuous with the fissura orbitalis superior at its inferior medial margin. The direction of this fissura inferior is forward and lateralward (at an angle of about 45 degrees) so that it marks the boundary between the lateral wall and the inferior wall of the orbit. This fissure is wider at its ends than at its mid-section, in which mid-section it is generally intersected by a groove, (Sulcus Infra-Orbitalis), which is the open superior border of the canalis infra-orbitalis (infra orbital canal), which is directed forward and medial to the fissura orbitalis inferior, and ends below the center of the margo inferior, on the facial aspect of the maxilla. The description of these three Foramina was given here, so that a general description of the walls of the orbita might be made, without again describing these canals when we come to a consideration of each wall; the other smaller foramina that open into the orbit will be taken up in conjunction with the parts described. The walls (Paries Orbitae) are not set at exact angles in their relations with each other, but the unions are rounded, and not at all well marked. Continuing the description, therefore, I will first detail the margo orbitae, followed by the paries orbitae.

The bones which form the margo orbitae are joined together by sutures known as Sutura Fronto-Maxillaris, Sutura Maxilla-Zygomatica, and Sutura Fronto-Zygomatica, so named

after the bones whose unions are thus designated. These sutures, like other sutures of flat bones, owe their importance generally to the fact that they mark the continuation of the periosteum and small vessels and nerves from one cavity, or space, to another, through which route and under which periosteum, pathologic effusions might pass.

The Margines Orbitae.

The contour of the margines orbitales, in their normal growth, and the relational change that they undergo, or the relational growth and developments of the surrounding features, seem to move the orbitae to a plane further back than they appear at birth.

The Margo Supra-Orbitalis (Supra Orbital Margin) is the horizontal anterior union of the pars frontalis and pars orbitalis of the Os Frontale (frontal bone). Its lateralward two-thirds is more rounded than its medialward end, at the junction of which it usually presents a notch (Incisura Supra-Orbitalis), through which pass the supra-orbital vessels and nerve, while just above the incisura supra-orbitalis, externally, there is in most cases a small opening, called the canalis supra-ciliaris (supra-ciliary canal), for the transmission of the supra-ciliary vessels. Sometimes the incisura supra-orbitalis is transformed into a canal, then designated Foramen Supra-Orbitale.

The Margo Medialis (Median Margin-Nasal Margin), is formed by the pars nasalis ossis frontalis (nasal process of the frontal bone) and the processus ossis frontalis maxillae (frontal process of the maxilla). The line of junction forming this border is rather like the lines of a circular spring, where the superior line will be somewhat lateralward to the inferior line, so that the descending line is continuous downward along the crista lacrimalis posterior of the os lacrimale, which is some 3.5 mm. lateralward and posterior to the ascending line. Between these two lines is the location of the apex of the saccus lacrimalis, and the question of the width of the aditus orbitae rests greatly on whether the anterior or posterior edge of the margo medialis is taken as the medialward place of measurement. This margin is the most in-

definite of all the margins, and on account of the protection afforded by the nose, is apparently not rounded and heavy like the other margins, as nature seems to have a defensive selection in its reinforcing of protecting bones.

The Margo Infra-Orbitalis (infra-orbital margin) is formed by the anterior border of the junction of the Facies Orbitalis, and the Facies Anterior of the Corpus Ossis Maxillae and of the Os Zygomaticum, these forming an equal part of this borer, being connected by the sutura maxilla-zygomatica. This border is thin, but well defined, and the medialward edge may show a slight groove, in which lies the infra-orbital artery. At the middle of this lower margin may sometimes be observed a slight prominence, which lies just above the exit of the Foramen Infra-Orbitale, named the Tuberculum Infra-Orbitale.

The Margo Lateralis (Temporal Border) is wholly formed by the margin of the Processus Temporalis (Zygomatic Process) of the Os Zygomaticum (Yoke Bone or Malar Bone); this is the strongest protective rim of the orbit, albeit it swings away from the anterior plane of the orbit, to allow a greater range of vision on that side. The superior ending of this margin is formed by the Sutura Zygomatico-Frontalis, which sutural irregular border, might be construed to lie within the limits of the margo lateralis.

At the mid-point of this well-defined margin may be seen a tubercle (Tuberculum Orbitale Laterale), which if present, while lying somewhat back on the paries lateralis, is projected forward enough to be noticed as taking part in the margin.

Paries (O. T. Walls).

The Paries Superior (Superior Wall) is the horizontal upper wall of the orbit and anteriorly is composed solely of the pars orbitalis ossi frontalis (orbital plate of the frontal bone) and posteriorly by the ala parva ossi sphenoidalis (lesser wing of the sphenoid). This wall is divided posteriorly by the sutura sphenofrontalis, which is the only suture that traverses the paries superioris, and marks the junction of the two bones forming this wall. The foramen opticum is not as much a part of this wall as of

the paries medialis, although its posterior border might be said to lie in this plane. This wall may be said to be slightly concave, with the depth of the concavity upwards.

Anteriorly on the medialward side is often seen a depression, Fovea Trochlearis, about 5 mm. back of the margo orbitae, for the attachment of the trochlear pulley, through which pulley passes the trochlear tendon of the M. obliquus oculi superior. Occasionally the posterior side of this fovea is accentuated enough to merit the name of Spina Trochlearis, where additional tendons of the pulley are attached.

At the lateralward anterior angle of the paries superior is the Fossa Glandulae Lacrimalis (Fossa of the Lacminal Gland) which is just behind the considerable overhanging margo supra-orbitalis, which, turning around downward, to assist in forming the superior end of the margo lateralis, is called the Processus Zygomaticus (Zygomatic Process); this fossa is rounded, and somewhat larger than the gland it accommodates. Posteriorly and inferiorly, belonging, in fact, to the paries lateralis, is an indistinct ridge at the sutura zygomatico-frontalis. This ridge marks the inferior boundary of the fossa glandulae lacrimalis.

The paries superior is quite thin, especially posteriorly, measuring about 1 mm. in thickness, but is subject to many variations, as it may be normally thickened, reinforced, or even doubled by the extension of the supra-orbital sinuses. These thickenings have no distinctive markings externally, and they are frequently quite out of proportion (larger or smaller) to what may be expected from the general surface appearance. However, the posterior portion is usually translucent, and presents a smooth arched surface. The usual aberrations of form caused by the thickenings and changes in the paries superior are found on the intracranial side and not on the outer, orbital side.

The Paries Lateralis (Temporal Wall) is composed of three bones, the medialward surface of the processus zygomaticus ossis frontalis (zygomatic process of the frontal bone), facies orbitalis ossis zygomatici (orbital surface of the zygomatic), and the ala magna ossi sphenoidalis (greater wing of the sphenoid). These

bones are separated by the sutura spheno-frontalis (spheno-frontal suture) and the sutura zygomatico-frontalis (zygomatic frontal suture) which separate the paries lateralis from the paries superior, while posteriorly these two walls are separated by the narrow superior end of the fissura orbitalis superior. The sutura spheno-zygomatica (spheno-zygomatic suture), is the vertical articulation of the greater wing of the sphenoid anteriorly with the orbital plate of the sphenoid, and leaves the two sutures, forming the horizontal superior angle, to course downward to the anterior margin of the fissura orbitalis inferior (inferior orbital fissure). The paries lateralis is separated from the paries inferior anteriorly by a line that would about parallel the general direction of the outer wall, which is about 45 degrees away from a sagittal line, and posteriorly by the fissura orbitalis inferior, which is also at about that angle.

The general direction of this wall from behind forward, is down and lateralward. This is by far the strongest wall of the orbit, and the bones forming it are each strengthened by supporting heavy processes.

The Foramen Zygomatico-Orbitale (Zygomatic Orbital Canal) opens in the anterior middle of this wall. Sometimes there are two or three internal openings here. The Fissura Orbitalis Inferior approaches the anterior margin about 17 mm. back of the margo lateralis.

The Paries Inferior (Inferior Wall) is formed by the facies orbitalis corporis maxillae (orbital plate of the maxillary body), posteriorly by the processus orbitalis ossi palatinis (orbital process of the palate bone), and lateralward by the horizontal portion of the facies orbitalis ossis zygomatici, (orbital plate of the zygomatic bone).

The lateralward boundary of this wall was described with the paries lateralis.

The median boundary is marked by the sutura lacrimo-maxillaris, (lacrimo-maxilla suture), the sutura ethmoido-maxillaris (ethmoidal-maxilla suture), and two of the three sutures of the triangular orbital plate of the palate bone, namely the spheno-

orbitalis and the palato-ethmoidalis. The palato maxillaris forms a part of the paries inferior, posteriorly. Anteriorly this wall is crossed by a part of the sutura zygomatico-maxillaris (zygomatic-maxilla suture).

This wall is inclined forward and downward and obliquely lateralward. The fissura orbitalis inferior, which occupies the posterior lateralward part of this wall, is closed off from the wall by the involuntary muscle of Müller. It is sometimes thought that by the contraction of this muscle the eyeball may be extruded from its socket. The rudimentary condition of its fibers makes this very improbable. This smooth muscle is interspersed with connective tissue fibers, and is supplied by sympathetic nerves only.

The junction of this wall with the medial wall is a rounded curve, which gradually leads the one into the other, and, while marked by the sutures, these walls tend to assume the same plane.

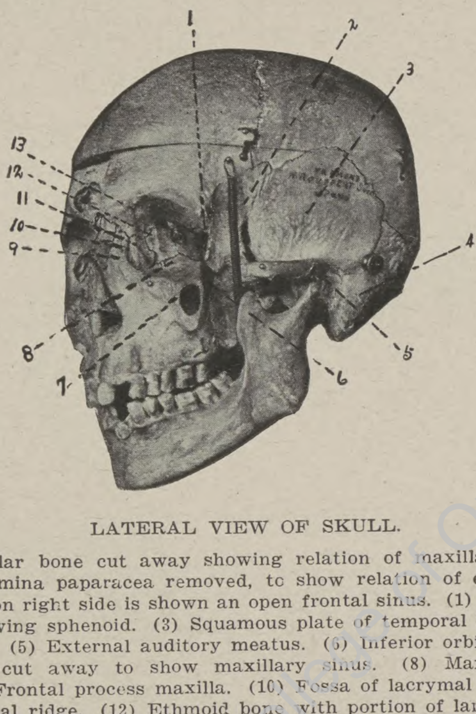
At the medialward anterior angle, behind the margo inferior, adjoining the naso-lacrimal canal, is sometimes found a depression, which may be felt rather than seen, where arises the obliquus oculi inferior muscle.

The paries inferior is thicker in front, near the margo inferior, but gets thinner behind, where it forms a thin partition about .065 mm. between the orbita and the Sinus Maxillaris (O. T. Antrum of Highmore).

The Paries Medialis, (nasal wall), is formed by the Os Lacrimale (Lacrimal Bone); the Lamina Papyracea Ossis Ethmoidalis (paper-like orbital plate of the ethmoidal bone), and the orbital surface of the corpus ossi sphenoidalis (body of sphenoid bone). The junction of this wall with the paries inferior was taken up in the previous paragraph.

This wall presents three vertical sutures: the Sutura Lacrimo-Maxillaris Anterior, between the os lacrimale and the processus frontalis maxillae, the Sutura Lacrimo-Ethmoidalis, between the lacrimal and the orbital surface of the ethmoid, and the Sutura Spheno-Ethmoidalis, between the orbital surfaces of the ethmoid and the body of the sphenoid. The superior junction of this wall

presents a horizontal suture, which is divisible into two sections, the Sutura Fronto-Lacramalis and Fronto-Ethmoidalis. These form a continuous suture, and separate the os frontale from the os lacrimale, anteriorly, and from the os ethmoidale posteriorly. The posterior portion of this suture is pierced by two foramina, Foramina Ethmoidales, Anterius and Posterius (Anterior and



LATERAL VIEW OF SKULL.

With malar bone cut away showing relation of maxillary sinus, also portion of lamina paparacea removed, to show relation of ethmoidal cells, while above on right side is shown an open frontal sinus. (1) Optic foramen. (2) Greater wing sphenoid. (3) Squamous plate of temporal bone. (4) Mastoid process. (5) External auditory meatus. (6) Inferior orbital fissure. (7) Malar bone cut away to show maxillary sinus. (8) Maxilla ethmoidal suture. (9) Frontal process maxilla. (10) Fossa of lacrymal sac. (11) Posterior lacrymal ridge. (12) Ethmoid bone with portion of lamina paparacea cut away showing ethmoidal cells. (13) Fossa of trochlea.

Posterior Ethmoidal Foramina). The borders of these foramina are equally divided between the os frontale and os ethmoidale. (However often found wholly in the os frontale). Posteriorly, in the same plane as the foramina ethmoidalia, lies the foramen opticum; it would, therefore, seem appropriate to consider it a part of the paries medialis, which seems the logical location for its

consideration. It is more often medial than superior, as shown on my chart of measurements.

The anterior part of the paries medialis presents the Os Lacrimale, which is divided by a vertical ridge, known as the Crista Lacrimalis Posterior, which crest forms the posterior border of the Fossa Sacci Lacrimalis which is continuous below with the Canalis Lacrimalis. This ridge makes a turn to form a spur around the superior lateralward edge of the canalis lacrimalis, to meet the posterior grooved border of the maxilla, the two grooves forming the completed fossa lacrimalis and the superior orifice of the Canalis Naso-Lacrimalis (Naso Lacrimal Canal).

The paries medialis is the thinnest of all the orbital walls, measuring about 0.3 mm. in thickness, although the thin papyracea lamina of the ethmoid is quite resistant and strong, as compared with some of the thicker walls. The direction of this wall is sagittal, so that the two walls of the two orbits are parallel. It is understood that this is a general direction, as there always are deviations to be considered.

The depth of the orbit is considered to be about 42.5 mm. This measurement however, is subject to many variations, principally because no definite landmarks have been accepted from which to take the measurement, so that figures from 38 to 48 mm. and more have been variously given. The figure, 42.5 mm. is from the mean origin of the ligament of Zinn to the anterior central position of the margo orbitae, which are certainly debatable points. The posterior end of the orbits correspond generally to the midpoint of a line drawn from the corneal apex, horizontally, to a vertical line at plane of the tragus.

Periosteum.

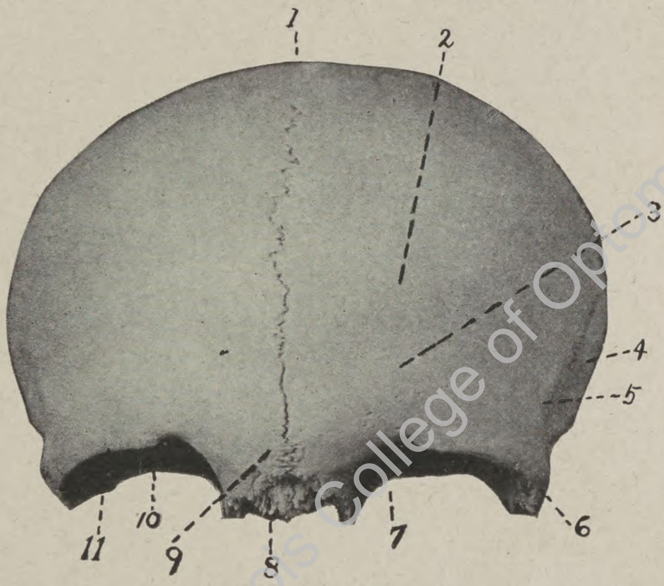
The Periosteum is the thin covering of bones in which are carried the nutritional vessels of the bone structure. In flat bones it is more adherent in some parts than others. In the development of bones, it covers all the surfaces, and is continuous around from one surface to another, so that when one surface articulates with another, the periosteum is incorporated in the suture, and where the suture persists, this periosteal highway is of pathological importance.

Where it meets a tendinous or ligamentous insertion, it becomes more adherent, and the periosteum is incorporated with them. Where it meets an orifice it becomes thinner, but continues through to cover the bone of the other side. The periosteum of the orbit (Periorbita) is no different, except that it is rather loosely adherent in the main vault, where it is thinner than at the orifices; the loose attachment tends to open an easy pathway for the pathologic effusions.

The close communication that the orbital periosteum has with the intra-cranial coverings, and also with the nasal periosteal extensions, makes this a subject of vital interest.

Orbital Bones.

There are seven bones forming the orbita, including its remote margins. To these bones are also attached certain accessory ap-



FRONTAL BONE.

Anterior surface.

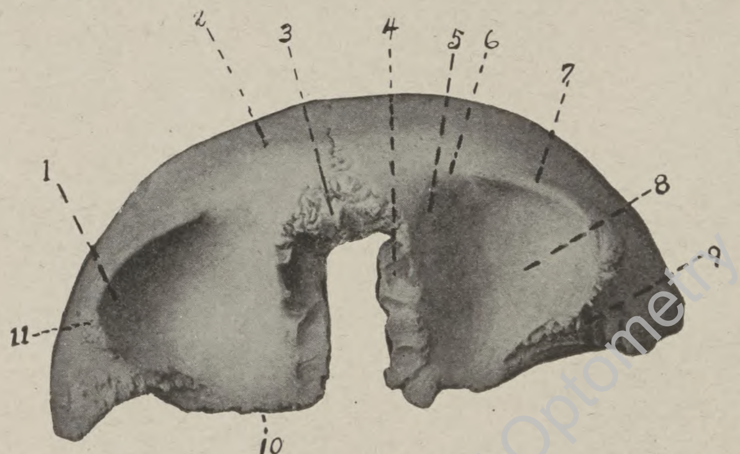
(1) Persistent frontal suture. (2) Frontal tuberosity. (3) Supercilliary arch. (4) Temporal surface. (5) Temporal ridge. (6) Zygomatic process. (7) Supra-orbital notch. (8) Nasal and maxillary articulation. (9) Glabella. (10) Orbital surface. (11) Supra-orbital margin.

pendages and structures having some extra-orbital interest. However, I shall describe the portions only of those bones which participate in the relational anatomy of the orbits.

The bones in question are: the Ossa Frontale, Lacrimalia, Ethmoidale, Maxillae, Palatina, Zygomatica, and Sphenoidale, named in the order of their description.

Os Frontale.

The Os Frontale (Frontal Bone) in infancy, is divided into two segments, by a vertical suture called the Sutura Frontalis



FRONTAL BONE.
Orbital surface view.

(1) Fossa for lacrymal gland. (2) Superciliary arch. (3) Articular surface for nasal bones. (4) Ethmoidal articulation (showing grooves of foramen). (5) Trochlear fossa (showing spine). (6) Supra-orbital notch. (7) Supra-orbital margin. (8) Orbital surface. (9) Fronto-sphenoidal articulation (large wing). (10) Fronto-sphenoidal articulation (small wing). (11) Zygomatic articulation.

(Frontal Suture or Metopi), which occasionally persists during life, but usually disappears about the fourth year.

The anterior surface (Squama Frontalis) of this bone shows two rounded elevations, one on either side of the sutura frontalis, about 30 mm. above the margo supra orbitae, called the Tubera Frontalia (Frontal Tuberosities).

Below each tuber frontale is a curved elevation known as the Arcus Superciliaris (Superciliary Arch). These arches are more prominent medialward, where, between the medial ends, is a flattened space named the Glabella. They are directed lateralward and upward, becoming less well marked on their lateral ends.

The greater or less prominence of these arches is no indication of the size of the underlying frontal sinuses. They are less prominent in the female, and less proportionately developed in children than in adults.

Below the arcus superciliaris is the margo supra orbitalis, where, at the junction of the medial third with the middle third, is a notch, sometimes converted into a foramen, named the Foramen Supra-Orbitale or Incisura Supra-Orbitalis, as the case may be, while medialward to this, may be a more shallow duplication of these, called Incisura Frontalis or Foramen Frontale.

These notches, or foramina, furnish a facial passage for the super-ciliaris vessels and nerves. The medial extremity of the margo super-ciliaris articulates with the Processus Frontalis of the Maxilla.

At the medial ending of the arcus supericiliaris, on its medial inferior border, is the place of origin of the corrugator superciliaris muscle.

At the lateralward ending of the margo superciliaris is the processus zygomaticus, which articulates with the processus frontosphenoidalis of the os zygomaticum.

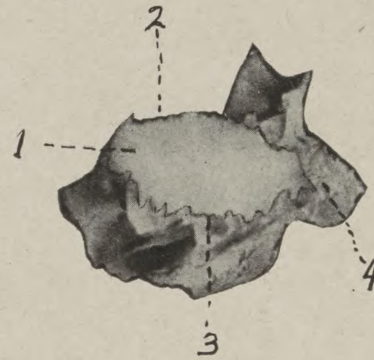
This external angular process is heavier than the medial portion, to give better protection to the orbital contents from the side. The paries orbitales (orbital surface), forms an angle of 90 degrees with the Squama Frontalis, of which we will consider only the Facies Orbitalis (Orbital Plate), which forms the paries superior and is described under that heading.

The Foramen Ethmoidale Anterius, of which this bone furnishes the superior half, or often the whole foramen, is the passage-way for the nasociliary branch of the fifth nerve and the anterior ethmoidal artery and vein; the Foramen Ethmoidale Posterius for the posterior ethmoidal branch of the fifth nerve and the posterior ethmoidal artery and vein. This posterior fora-

men is often duplicated, while in some cases three openings are noted.

Os Ethmoidale.

The Os Ethmoidale (Ethmoid Bone), by its Lamina Papyracea (paper plate), forms the greater extent of the paries medialis



ETHMOID BONE.

(1) Lamina papyracea orbital surface. (2) Articulation with frontal. (3) Posterior ethmoidal cells. (4) Anterior ethmoidal cells.

of the orbit. This surface is of particular interest, in that it divides the orbit from the middle and posterior ethmoidal cells.

Os Lacrimalia.

The Os Lacrimalia (Lacrimal Bone) is a thin, small, fragile bone which lies at the anterior medial margin of the orbit. Its orbital surface shows a ridge in a vertical direction called the Crista Lacrimalis Posterior (Lacrimal Crest) for the origin of the pars lacrimalis musculi orbicularis oculi (lacrimal part of the orbicularis oculi muscle or tensor-tarsi portion) and the reflected portion of the medial palpelral raphe. Inferiorly this crest takes a forward turn into a so-called curved projection, called Hamulus Lacrimalis (Hamular Extension) which articulates, anteriorly, with the incisura lacrimale (lacrimal notch) of the maxilla, to complete the superior opening of the canalis naso-lacrimalis.

The lacrimal crest of this bone divides the orbital surface into two portions, the posterior flat portion, looking lateralward, form-

ing the anterior margin of the paries medialis, while the anterior portion, looking forward, is somewhat concave, to form the posterior medial half of the Fossa Sacci Lacrimalis (Fossa for the Lacrimal Sac). This is a very fragile bone and very variable in size, it is referred to as "a diminishing remains of the os lacrimale, which is so prominent in animals." (See measurements.)

Maxilla.

The Maxilla (Superior Maxillary Bone) forms the inferior half of the margo orbitae medialis, and the medial half of the margo orbitae inferior. The processus frontalis (frontal process) of the maxilla articulates in front with the pars nasalis ossis frontalis (part of nasal process of the frontal bone). On its orbital edge is noted a ridge almost in a vertical direction; this is called the Crista Lacrimalis Anterior (Anterior Lacrimal Crest), and behind this crest is a groove, which, looking posteriorly and lateralward, forms the front half of the fossa sacci lacrimalis (fossa for the lacrimal sac). Below this groove the naso-lacrimal canal is mostly contained in the nasal wall of the maxilla. At the front center of the crista lacrimalis anterior is attached the medial palpebral raphe, while above and below this attachment, on this anterior border, is the origin of the orbicularis palpebrarum muscle.

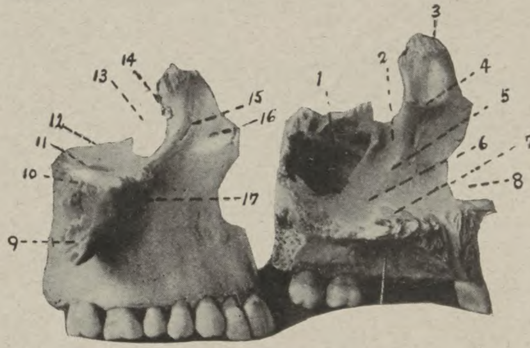
Joining this muscle at its lower medial origin, arises the levator labii superioris alaeque nasi muscle.

Below the margo orbitae inferior is the origin of the levator labii superioris, while below this, on the facial aspect, is the foramen infra-orbitale, through which emerges the infra-orbital nerve and vessels.

The Facies Orbitalis, or Planum Orbitale, furnishes the main portion of the paries inferior. On its medial anterior angle it presents a notch (Incisura Lacrimalis) which forms the lateral side of the Fossa Sacci Lacrimalis. On the lateral side of this groove, or notch, is often a small fossa, where arises the inferior oblique muscle.

The posterior border of this orbital plate is the anterior border of the fissura orbitalis inferior (inferior orbital fissure), and

near the middle of this free border is a groove, Sulcus Infra-Orbitalis, to accommodate the infra-orbital vessels and nerve. This groove takes a lower plane anteriorly, so that the groove becomes a canal by being covered over by the orbital plate of the maxilla. The posterior canal opening may start as far back as the fissura orbitalis inferior.



MAXILLA.

Lateral and medial views.

(1) Maxillary sinus. (2) Lacrymal groove. (3) Frontal process. (4) Ridge for middle concha. (5) Ridge for inferior concha. (6) Inferior meatus. (7) Nasal crest. (8) Nasal notch. (9) Zygomatic process. (10) Zygomatic maxilla suture. (11) Infra orbital groove. (12) Maxilla ethmoidal articulation. (13) Lacrymal notch. (14) Grooves for infra orbital artery (Sutura longitudinalis imperfecta). (15) Frontal process of maxilla (16) Infra orbital foramen.

The orbital plate of the maxilla is quite thin, and separates the orbit from the Hiatus Maxillaris (Maxillary Sinus, Antrum of Highmore).

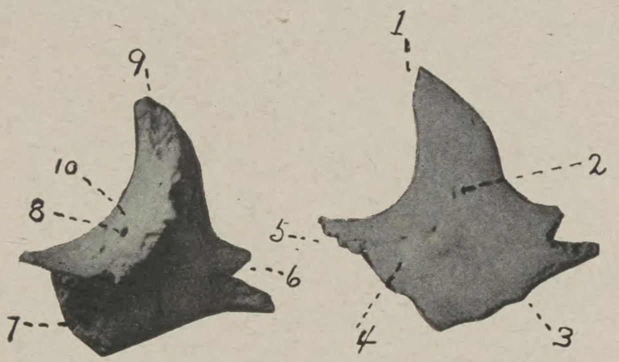
Os Palatinum.

The Os Palatinum (Palate Bone) sends up a small platelet to form a portion of the posterior end of the paries inferior. The sutures of its articular edges usually disappear in the adult. This platelet is triangular in shape and is called the Processus Orbitalis Ossis Palatini (Orbital Process of the Palate Bone).

Os Zygomaticum.

The Os Zygomaticum (Malar Bone, Yoke Bone) lies on the lateral side of the orbit, and forms the lateral margin and the

lateral half of the margo inferior. Just within the orbital margin, on the lateral side, about the middle of the processus fronto-sphenoidalis, is a slight tubercle which gives attachment to the lateral palpebral raphe. On the orbital plate, at about the junction of the lateral with the inferior wall, about 10 mm. behind the margin, is seen the common opening of two canals, one of which



ZYGOMATIC BONE.

(1) Frontal process. (2) Zygomatico facial canals. (3) Massenteric border (4) Facial surface. (5) Maxillary border. (6) Temporal process. (7) Maxillary articulation. (8) Zygomatic facial canal. (9) Fronto-sphenoidal articulation. (10) Orbital surface.

opens on the facial aspect of the os zygomaticum, through which passes the malar facial nerve, and the other into its temporal fossa through which passes the malar temporal nerve.

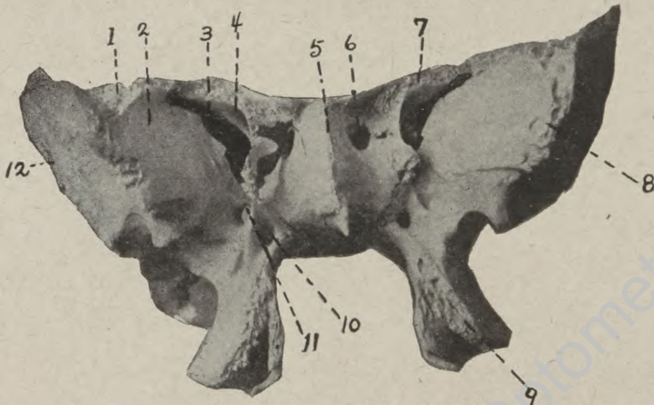
At its articulation with the orbital plate of the maxilla, the os zygomaticum usually forms the anterior boundary of the fissura orbitalis inferior.

Os Sphenoidale.

The Os Sphenoidale (Sphenoid Bone), by its alae parvae (small wings), and alae magnae (large wings), forms the apex and the posterior lateral wall of the orbits.

The medial edge of the large wing of the sphenoid forms the lower lateral verge of the superior orbital fissure. This fissure is divisible into two distinct portions, a medial quadrilateral portion, that is situated at the apex of the orbit, and a lateral narrow

upper portion that divides the lateral from the superior wall. On the lateral edge of the quadrilateral portion is a longitudinal tubercle (it may be well marked, rudimentary, or absent) which gives attachment on that side to the annular ligament of Zinn, as it swings around over this foramen, to which ligament is attached the four recti muscles, the superior oblique, and the levator palpebrarum superioris. This Annulus of Zinn is about 3 or 4 mm. in width, and swings around this opening and also around the optic canal. There are posterior extensions of this tendon, as well as



SPHENOID BONE.

Front view.

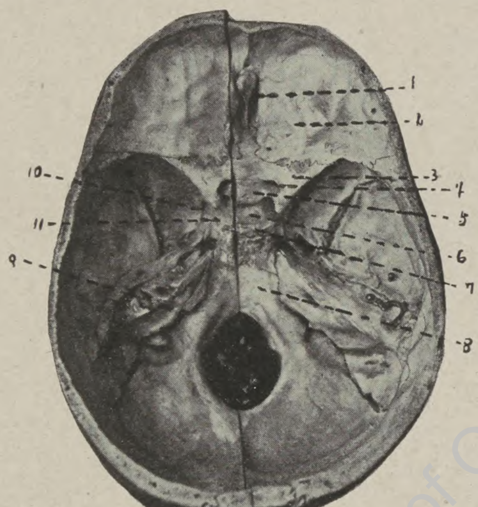
(1) Sphenoid frontal articulation. (2) Orbital surface. (8) Superior orbital fissure. (4) Optic foramen. (5) Body sphenoid (sphenoidal spine) (6) Sphenoidal sinus (on opposite side note the close approximation to optic foramen. (7) Lesser wing sphenoid. (8) Malar articulation. (9) Pterygoid process. (10) Pterygoid canal. (11) Foramen rotundum. (12) Temporal surface.

anterior fasiculi, going into the small bridge of bone that separates these two foramina.

The attachment of this ligament of Zinn seems to be the most plausible explanation of the apical entrance of the muscular funnel, and my disections seem to confirm this relational condition. I have not been able to confirm the division of the head of the external rectus at this point.

The small wings of the sphenoid form the superior verge of the superior orbital fissure.

The Alae Parvae arise by two processes, from the body of the sphenoid by a superior thin and an inferior thicker process, between which processes is the foramen opticum. The superior process is 5 mm. wide, and the inferior 9 mm. wide, and these widths measure the length of the Foramen opticum. The external and internal openings are oval, while the middle portion is round.



BASE OF SKULL FROM ABOVE.

Showing inter cranial roofs of orbits and cranial openings of optic foramen. (1) Cribrifrom plate and ethmoidal foramen. (2) Intercranial roof of orbits. (3) Small wing of sphenoid. (4) Foramen opticum. (5) Tubercullum sellae of the sphenoid. (6) Fossa of the hypophysis. (7) Clinoid process. (8) Location of medulla. (9) Dissection of semicircular canals. (10) Foramen rotundum (11) Position internal carotid artery.

The axis of this canal is at an angle of at least 45 degrees from a sagittal plane.

When looked at from the front, it lies in the general plane of the medial wall, as only the posterior side of the orbital end can be seen from that position, which posterior portion may lie

in the plane of the superior wall. While in the many skulls which I have observed, I have found only very few in which it could be positively stated that the foramen opticum lay wholly in the roof of the orbit, perhaps the position might be changed in a more extended investigation, but in the several hundred I have examined, the opening is certainly medial. (See measurements.)

CHAPTER VII.

Measurements of the Orbit.

In undertaking the measurements of the Human Orbits in this table, I was influenced by the almost universal statement, that their measurements usually were of slight value on account of the indefinite points from which they were taken, as to the beginning and the distal points.

I am indebted for the opportunity of the investigation, to the kindness of Dr. Laufer, of the Anthropological Department of the Field Museum of Natural Sciences of Chicago, who kindly selected and put at my disposal several hundred of these specimens.

These selections were made at random, both by Dr. Laufer and myself to show a general view of Ancestral American characteristics as relates to the orbit, without having in view any particular single line of anthropometric trait.

The Height (A) is taken from the margin of the orbit, vertically, as near the center as possible.

The Width (B) to "Flower's Point," is taken from the middle of the Tubercle Laterale (if present), or the corresponding position, on the edge of the Margo Lateralis, to the superior point of the Posterior Lacrimal Ridge, known as "Flower's Point."

The Width (C) to "Dacryon Point," which point is the superior junction (if present) of the Sutura Lacrimo-Maxillaris.

The Width (D) to the anterior crest, is as the others, from the common lateral point, to the superior point (or a corresponding position), of the Anterior Lacrimal Crest.

The reason for the measurements to the medial points having such a great variation, lies in the differences in the size and shape of the Os. Lacrimale.

There is no bone of the body, that takes on a more varying size and shape. The changes are modified chiefly by the development forward to the Lacrimal ridge, influenced by the development of the nose after birth.

The portion of this bone, which forms the medial and posterior boundary of the superior lacrimal fossa, may be rudimen-

tary, and hardly leave the posterior plane of that fossa, but again it may be broad and fill out nearly all the medial wall of that space, so that the "Dacryon Sutura Apex," as an omni-present measuring point, as shown in (C), is of slight value, while "Flower's point" is more constant, and the anterior crest (D) is almost valueless.

ORBIT OF SKULL.

Marked to show the various transverse diameters as discussed in my tables of measurements, the vertical diameters and the depth of course would vary according as one or the other points were used, the X is at the anterior margin of the foramen opticium, while the spot is the point of greatest depth (which I used) of the orbit. The cheek (C) to glabella (G), and nose (N) to temple (T) show the direction of the oblique measurements. The arrow shows the distance of the infra orbital foramen from margin.

One of the striking peculiarities of the posterior lacrimal ridge is found in grave skulls, where the soft parts have disappeared gradually, leaving the bone intact. This ridge is more than often plate-like, to form in fact, an almost complete lateral bony covering of the saccus lacrimalis, especially at the apical

end, and this plate persists all during life—in skulls cleaned for anatomical specimens, this thin bony plate is generally missing.

The orbital margins are developed after birth, in conformity with the other facial developments, so that the many points of measurements of the varying rounded boundaries, are necessarily artificial and not always exact, as a margin may be rounded or angular, and the planes taken by the edges may vary in the same skull, so that, with the best intentions, there may be a variation on the part two individual investigators, I might add that these measurements are all straight measurements, to points perpendicular, where necessary, and none are curved or angular measurements, while capacity measurement has not been considered.

A. H. Tubby, in his article concerning the connection between the skelatal asymmetry and defects of the eye, read before the ophthalmological congress of Oxford in Session 1919, concludes "that the balance of the Eye, the phorias, are tended to be corrected when the orthopedist has corrected the asymmetries." While he suggests that the asymmetries of the skull might cause visual deformities, yet he touches this subject very lightly—it is well known that most asymmetries occur after birth, as there is a general unmoulding of the skull at birth which from then on takes on another growth.

These suggestions as to the post-natal asymmetries are very interesting, as the unmoulding is found almost universal, except as regards the orbit and the internal ear, which, in my opinion have a fixed relational position.

The Inside height (E) back of the margin, is taken about 2 mm. back of anterior margin, so as to show the greatest height of the orbit. This, like all other measurements, depends greatly on what is considered the marginal point. The vertical measurement points are the ones here considered.

The Trochlear height (F) is taken from the trochlear fossa above to the fossa of the inferior oblique below (which if neither is present are guessed at). In the forty-one skulls, recorded there were only six, in which these points were clearly demonstrable. The points are generally supposed to be directly in a vertical line

with each other; in these well marked cases the lower point was always 5 mm. lateral to the upper point. In only two of the forty-one skulls, was there an accompanying Tubercle with the superior trochlear fossa.

The Depth (G) is taken with a steel rod, the end of which is grooved, to straddle the posterior margin of the optic foramen, the anterior end meeting the vertical height line of the margin, therefore the axis direction is about the central depth direction, these measurements are in variance with some others, in that they are taken from the greatest depth to the greatest marginal position, while the real depth of the orbit should be the physiologic depth, or from the anterior margin of the optic foramen, which lies about 4 to 8 mm. anteriorly.

The Wall Depths (H-I-J-K) are self explanatory. They begin at the same posterior position, and are straight lines to a perpendicular.

The Obliques (L) are taken at right angles with each other, the first from the cheek slanting about 45° towards the glabella, and the second bisecting this line measuring from margin to margin. The lateral obliquity of the floor not being taken into consideration.

Optic Foramen Position and Direction (M & N): The foramen position is more often a part of the medial wall than of the roof, where it is rarely wholly situated; often however it is partially situated above the medial wall and when so it is designated by R. M. The Axis direction of the foramen is so often at an angle of 45° that this may be considered as the normal axis direction; all others as a deviation from the normal.

The lateral tubercle on the edge of the superior orbital foramen (O) is variable, as to its presence or absence. When present, its size varies from a spinous point to a longitudinal ridge, from 2 to 5 mm. in length.

The Infra Orbital Foramen (P) vary as to their distance away from the margin of the orbit, as shown in the table. In the lower types these are usually further away. This greater distance is especially noted in the larger apes.

The Position of the Orbits (Q) shows that the majority of the orbits are lower on the right side than on the left, also that the floor of the right side is often lower than is the roof of the same side, as compared with the corresponding left floor and roof. In other words the asymmetry of the two orbits does not depress these two surfaces to the same corresponding planes.

The direction of the Lacrimal Canals or Nasal Ducts are quite as often parallel as inclined. When inclined they diverge from the top, at about an angle of 20 degrees.

The Ethmoidal Foramen (S & T) are generally present; the posterior, however, may be absent, or in other cases in two or three divisions. Generally they are situated, especially the anterior, further back than the literature would lead us to believe. (The anterior is about 25 mm. back of orbital margin.)

The Lateral Zygomatic Tubercle (V) is often absent, and is quite rudimentary in many of the "Present" cases, so that some anatomists have not described it as an anatomical entity.

The direction of the medial wall, which is at all times rounded, shows a general parallel direction, especially along the superior border, which is the characteristic border.

The direction of the Lateral Walls (X) are normally 45° from the sagittal axis; any deviation from this seems abnormal.

The direction of the median level of the floor (Y) from a horizontal plane is depressed anteriorly, forming an angle of 20°, with the apex of the angle at the optic foramen.

The distances between the Lateral Orbital (Z) margins, are subject to a great variation; this variation no doubt influences myopia and hypermetropia, from the fact, that a widely separated pair of eyes, must have a greater strain put on them for convergence, so this strain may effect the shape of the eyes, as is claimed by some anatomists.

The presence or absence of the Supra-Orbital Foramen (B^2) is inconsequential, but given here because spoken of in books.

I find the distance of the Lateral Orbital Margins further

back than usually given—(C^2). The usual distance is given as 12 or 13 mm.

Averages for 41.			Variations.
35.75	Height	R.	31——44
35.	Height	L.	30——41
38.22	Width "Flowers" Point	R.	34——46
38.35	Width "Flowers" Point	L.	33——45
40.01	"Dacryon" Point	R.	35——47
40.16	"Dacryon" Point	L.	34——47
42.15	"Dacryon" Anterior Crest	R.	37——51
42.	"Dacryon" Anterior Crest	L.	36——48
37.53	Height Inside Center	R.	32——41
37.71	Height Inside Center	L.	33——41
30.25	Height Trochlear	R.	23——37
30.45	Height Trochlear	L.	26——35
47.80	Depth Central	R.	39——54
46.92	Depth Central	L.	40——53
50.72	Depth Roof	R.	45——60
51.46	Depth Roof	L.	45——61
48.58	Depth Floor	R.	39——57
48.12	Depth Floor	L.	46——57
46.85	Depth Lateral	R.	40——54
46.77	Depth Lateral	L.	43——52
42.62	Depth Medial	R.	35——48
42.40	Depth Medial	L.	38——48
98.20	Greatest Widths, Outer Margin		86——110
79.50	Distance from Anterior Margin Bony Aural Canal, to Dacryon Point on a Horizontal Plane		70——90

No.	Register	Origin of specimen - Field Museum of Natural History, 1922, September	A Height Center to center (R L)	B Width to Flowers point (R L)	C Width to Dacryon point (R L)	D Width to anterior crest (R L)	E Height internal 2 mm. back of margin (R L)	F Height trochlear (R L)	G Depth central to height line (R L)	H Depth roof (R L)	I Depth floor (R L)	J Depth lateral (R L)	K Depth medial to dacryon (R L)	L Obliques cheek to glabella (R L)	M Obliques cheek to glabella left (L)	N Optic foramen position (R L)	O Optic foramen axis direction (R L)	P Tubercle sphenoidal present or absent (R L)	Q Infra-orbital foramen distance away (R L)	R Orbits position high, low, level (R L)	S Lacrimal canal direction (R L)	T Anterior ethmoid foramen (R L)	U Posterior ethmoid foramen (R L)	V Posterior lacrimal ridge (R L)	W Lateral zygoma tubercle (R L)	X Direction medial wall (R L)	Y Direction lateral walls (R L)	Z Direction floor (R L)	A^2 Distance lateral orbital margins (R L)	B^2 Distance anterior margin auditory canal to plane of dacryon	C^2 Supra-orbital notch and foramen (R L)	D^2 Width between lacrimal points	E^2 Distance between plane lateral margin and dacryon plane
1.	40357	Chueta Boliva, W. E. Oruro Gift 1891	33 33	34 33	35 34	37 36	35 36	29 29	44 45	48 48	47 47	43 43	41 42	39 35	38 37	RM RM	40 40	A A	8 8	L^4M	20 20	P P	P P	P P	P P	Par	45	20	86	74	N N	19	10
2.	40356	" " " " " "	39 39	40 38	41	44 42	41 41	31 -	47 47	52 51	50 50	47 46	44 44	47 40	47 40	RM RM	45 45	A	10 9	L^2M	- -	P P	P P	P P.	- -	Par	45	20	98	81	N N	21	16
3.	40299	Bridge nose right angle to face Climbote, Peru, 1891	34 35	41 42	45 45	45 45	34 34	27 27	44 46	48 49	49 48	47 46	42 42	45 40	45 40	RM RM	45 45	Pt Pt	7 6	L^3M	Par	P P	P_2 P_2	Marked	P P	Par	45	20	102	78	N^1 N^1	21	20
4.	41806	Northern Iroquois, N. Y. Frank Boas cranium of chief	33 34	40 42	42 44	45 46	38 38	30 30	54 51	60 61	55 51	53 52	43 49	45 37	45 39	M M	45 45	2m 3m	6 6	L^1M	20 20	P P	P_2 P_2	"	A A	Par	45	20	105	83	N^1 N^1	26	16-20
5.	41801	Auburn, N. Y. Iroquois	35 35	38 38	40 40	42 43	38 38	- -	48 46	51 52	48 48	47 47	44 -	41 38	41 41	RM RM	45 45	A A	4 4	Level	20 20	P P	P P	-	P P	Par	45	20	95	78	N^1 N^1 F^1	21	15
6.	42750	Tesontepee, Mexico, prehistoric	37 35	39 37	39 39	42 42	- -	30 -	47 47	51 51	49 48	48 47	44 44	43 37	41 38	RM RM	45 45	A A	6 6	L^5M	20 20	P P	P P	P P	A A	Par	45	20	100	80	N^1 F^1 F^1 N^1	21	16
7.	40592	Flemtlemlets, B.C., Canada, Frank Boas - young woman	35 34	36 36	37 38	40 40	36 36	30 30	45 44	47 47	48 48	44 45	41 41	40 39	39 40	RM RM	45 45	4m 4m	6 7	L^2M	10 10	P P	P P	Marked	A A	Par	45	20	90	76	N^1 N^1	21	17
8.	42941	Paris, France Purchase - frontal suture present	38 36	38 36	38 38	42 40	37 36	27 27*	47 45	50 49	48 46	43 44	42 42	43 37	43 45	RM RM	45 45	A A	5 5	Level	20 20	P P	P_8 P	P P	P P	Par	45	29	100	80	F^2 F^1	29	20
9.	40237	Cuzeo, Peru Purchased E. Montez	38 38	36 38	38 38	40 40	39 39	- -	44 44	45 47	46 46	41 45	39 39	43 38	42 37	RM RM	45 45	Sp 3m	7 6	L^1M	Par	P P	P_2 P	P P	P P	Par	45	20	97	78	A A	24	12
10.	40213	Ancon, Peru	40 38	38 38	40 40	43 43	- -	31 31	46 45	50 50	49 46	47 48	40 40	42 37	42 38	M M	35 35	A A	2m 2	L^3M	20 20	P P	P P	Marked	P P	Par	45	20	98	81	N^1 F^1	22	16
11.	40230	Huaraconda Inca, Peru, 1892	37 35	35 36	37 37	40 38	- -	31 31	45 45	49 49	48 48	45 45	43 41	40 38	42 40	RM RM	45 45	Sp 6m	7 7	L^2M	Par	P P	P P	P P	A A	Par	45	20	92	75	N^1 N^1	22	17
12.	41767	Jersey Co., Ill. Mound Builders Frank Boas, Purchased 1891	36 37	39 40	40 42	45 43	-	- -	44 44	50 50	45 45	43 44	- 43	45 39	46 42	RM RM	45 45	P P	7 7	L^3M	20	P P	P P	P P	P P	Par	45	20	102	85	N^1 N^1 F^1	26	17
13.	40294	Sierra Gorda, Peru. George A. Dorsey Gift 1891	34 35	39 40	41 41	44 44	- -	- -	45 46	47 47	46 46	45 46	43 42	43 38	42 40	RM RM	45 45	P P	10 10	L^4M	20	P P	P P	Plate like	P P	Par	45	20	96	75	N^2 N^1	21	18
14.	40407	Amatch Tucuman, Argentine, purchased	37 36	37 37	39 39	41441	- -	29 29	43 44	50 51	47 46	45 48	43 -	44 38	43 39	RM RM	45 45	A A	3 2	L^3M	Par	P P	P P	"	P P	Par	45	20	100	82	F^1 F^2 N^1 N^1	23	13
15.	40189	Ancon, Peru, George A. Dorsey Gift 1891	38 34	40 40	41 41	43 -	- -	28 28	39 40	45 45	39 45	40 40	35 40	44 39	[illegible]	RM RM	45 45	3m 3m	5 7	L^4M	Par	P P	P_2 P_1	"	P P	Par	45	20	100	78	N^1 N^1	21	19
16.	43321	New Ireland	35 36	39 40	43 42	44 45	- -	31 30	49 48	52 54	49 48	47 49	44 44	42 38	42 42	M M	45 45	P P	8 8	L^2M	20	P P	P P	Plate	P P	Par	45	20	100	82	N^1 N^1	23	12
17.	40122	Ancon, Peru. George A. Dorsey Gift 1891	35 34	35 36	41 39	43 41	- -	- -	43 43	48 48	45 45	44 44	39 38	42 35	39 35	RM RM	45 45	P P	5 6	L^3M	20	P P	P P.	"	P P	Par	45	20	90	70	F^2 F^2	19	15
18.	43184	Gazelle Penn. New Britain purchase	36 34	39 38	40 39	42 44	37 37	31 31	49 49	57 58	49 51	47 47	45 44	44 42	42 37	M RM	45 45	P P	6 7	$L^4$2m	Par	P P	P P	"	Absent	Par	45	15	99	82	N^1 F^2 F^1	19	16-20
19.	43236	" " " " "	36 37	38 37	40 39	43 42	37 36	29 29	42 45	48 46	44 47	42 45	40 40	45 40	45 40	RM RM	45 45	A P	Vert 6 6	L^4M	Par	P P	P P	P P	P P	Par	45	20	97	76	N^1 N^1 F^1 F^1	21	18-16
20.	43200	" " " " "	31 30	39 38	- -	44 42	32 33	29 31	54 53	54 57	52 52	50 51	- -	47 40	45 40	M M	25 25	P A	9 12	L^6M	Par	P P	A P	Plate	A A	Par	45	20	105	85	N1 N^1	28	20-13
21.	40922	Cumshewa, British Columbia, Haida	39 38	41 40	42 42	46 44	41 41	37 35	53 52	57 57	57 57	49 48	47 48	49 43	49 41	M M	45 45	Sp Sp	8 8	L^3M	Par	P_2 P_2	P P	Marked	P -	Par	45	20	105	90	F^1 F^2	24	18-20
22.	40083	A ncon, Peru, 1891 Gift	34 35	40 40	41 41	44 44	38 39	34 34	48 48	50 51	48 49	49 48	40 40	45 39	43 39	RM RM	45 45	A A	7 8	L^2M	20	P P	P P	Plate	P P	Par	45	20	102	82	F^1 F^1	20	12
23.	40899	Queen Charlotte Islands, B. C. Neustints	38 38	41 41	43 42	46 44	41 41	35 35	53 52	55 57	55 53	52 51	44 45	49 42	47 40	RM RM	45 45	A A	8 8	L^2M	20	P P	P P	"	A A	Par	45	20	107	78	F^1 F^1 N^1 N^1	23	15-17
24.	40870	Queen Charlotte Islands, B.C. Spedans	38 37	42 43	- 44	47 46	40 40	34 34	50 53	57 56	50 50	50 51	44 45	47 42	42 42	M RM	45 45	Sp Sp	9 8	L^3M	20	P P	P P	"	A A	Par	45	20	110	92	F^1 F^2 N^1	23	15
25.	40889	" " " ", Neustints	41 41	46 45	47 47	51 48	41 41	33 33	53 49	56 55	53 49	52 50	48 46	48 45	47 46	M M	45 45	Sp Sp	4 4	L^2M	20	P P	P P	P P	P P	Par	45	29	110	85	F^1 F^3 N^1	23	15
26.	40869	" " " ", Skidans, Haida	37 38	41 41	- -	45 45	38 39	30 -	48 48	53 51	47 46	47 48	43 -	48 41	48 44	M M	45 45	Sp Sp	7 7	L^5M	Par	P P	P P	P P	P P	Par	45	20	105	78	N^1 N^1	23	18
27.	43246	Gazelle, Penn. New Britain	33 32	37 38	39 40	42 42	35 35	26 26	49 49	53 53	51 51	47 48	45 45	42 40	40 40	M M	45 45	Sp Sp	9 7	L^3M	Par	P P	P P	P P	P P	Par	45	20	96	83	F^1 F^1	23	10
28.	41504	Lytton, British Columbia -young person	33 33	37 37	40 39	43 41	34 36	23 -	48 48	52 52	51 49	47 49	46 46	43 35	40 37	RM RM	45 45	3m	7 8	L^1M	20	P P	P_2 P_3	Plate	A A	Par	45	20	95	82	N^1 N^1	21	12-15
29.	41500	Cheinunsius, Vancouver, B.C. mis-shapen	39 39	41 41	42 43	48 45	40 40	30 30	51 48	57 57	51 48	54 59	46 45	48 43	47 41	RM R	45 45	A A	8 6	L^5M	20	P P	P P	"	P P	Par	45	20	105	82	N^1 N^1 F^1 F^1	24	8-15
30.	41816	Cross County, Arkansas - calabrium	38 37	35 35	37 36	40 40	- -	- -	47 46	51 55	48 48	46 47	42 41	42 38	41 40	M M	45 45	A A	3 5	H^1M	Par	P P	P P	Marked	P P	Par	45	20	90	80	F^2 F^1	-	15
31.	41817	" " " "	39 38	37 35	38 38	40 40	- -	- -	46 45	48 49	46 48	44 44	40 40	43 40	45 36	M M	35 35	A A	5 5	$H^{1/2}M$	20	P P	P P	"	P P	Par	45	20	90	72	F^1 F^1 N^1	-	-
32.	42936	German, 1893 - cranium	35 35	36 38	38 39	40 40	- -	- -	49 49	50 50	48 48	46 48	43 43	40 41	42 43	RM RM	45 45	4m 4m	3 5	H^3M	Par	P P	A A	P P	P P	Par	40	20	96	80	N^1 N^1	-	-
33.	41818	Cross County, Arkansas - cranium	35 35	40 39	42 41	44 42	- -	- -	50 48	54 50	50 50	47 46	44 44	45 42	45 41	M M	45 45	A A	8 7	-	30	P P	P P	Marked	A A	Par	45	15	100	80	F^1 F^1 N^1	-	18-16
34.	40149	Massive skull Ancon, Peru, receeding forehead	36 37	40 39	43 42	45 43	- -	- -	44 45	46 46	46 46	45 44	38 38	44 44	44 45	M M	45 45	2m 2m	6 5	H^2M	20	P P	P P	"	P P	Par	45	-	103	73	N^1 N^2	-	15
35.	42938	Cranium of an idiot Vecinia Airstrum	37 35	38 38	40 41	42 41	- -	- -	47 47	52 52	47 48	45 45	40 40	42 40	43 37	RM RM	45 45	Sp Sp	5 5	H^3M	20	P P	P P	"	P P	Par	45	-	98	75	F^2 F^2	-	20
36.	42835	Cranium of Robt. Howard Metcalf murderer	36 34	37 37	- -	40 40	- -	- -	45 45	51 51	47 47	44 43	40 40	46 40	46 38	RM RM	45 45	2m	3 4	L^2M	20	P P	P P	P P	P P	Par	45	25	98	85	F^1 F^2	-	25-20
37.	43241	New Britain, Gazelle, Penn. Peru.	34 34	- -	- -	40 48	- -	- -	52 50	56 54	52 51	50 47	- -	45 40	45 40	M M	45 45	A A	10 10	L^1M	15	P P	P P	"	A A	Par	45	20	103	83	N^1 N^1	-	-
38.	42700	San Miguel Island, Santa Barbara, Calif.	35 35	37 [illegible]	40 37	41 38	- -	- -	47 47	51 51	49 49	46 45	40 40	40 39	39 37	M M	35 35	A 2m	4 3	L^3M	5	P P	P P	Marked	A A	Par	45	20	95	70	F^2 F^2	-	15
39.	43409	Asop German New Guinea 1910 Exped.	34 33	35 36	33 37	39 38	- -	- -	50 52	54 54	51 51	48 48	45 46	42 40	38 37	M M	45 45	P P	11 10	L^2M	Par	P P	P P	P P	P P	Par	45	20	95	82	F^1 N^1	-	15
40.	43408	" " " " " "	34 33	37 37	40 39	40 39	- -	- -	50 50	56 55	50 50	46 44	46 44	41 41	40 40	RM RM	45 45	P P	9 9	L^1M	Par	P P	P P	P P	P P	Par	45	-	98	72	F^1 F^1	-	15
41.	40995	Flat Head Indian Chinook, Oregon	38 37	- -	- -	40 40	- -	- -	49 48	51 51	50 50	49 49	- -	45 43	43 43	M M	45 45	P P	6 6	Level	Par	P P	P P	- -	- -	Par	45	-	100	85	A A	-	20

Key.
A. = Absent.
P. = Present.
L. = Lower.
H. = Higher.
Par. = Parallel.
R. M. = Roof and medial.

M. = In same col-medial.
Plate = Plate-like rather than ridge.
N^1 = Notch one.
3 m = (3) Three millimeters.
Pt. = Point.
Sp. = Spine.

Numbers refer to millimeters or degrees.
Lacrimal canal direction either inclines 20° outward from top or are parallel.
Distance from anterior margin of auditory canal to plane of dacryon is horizontal distance and not angular.
Width between lacrimal points is between "Flowers" points.
F^1 = Foramen one.

THE AVERAGE MEASUREMENTS OF LITERATURE.

WIDTH

	Males	Females	Children
Ethert	41.6	39.8	34.3
Vierort	36		
DeWecker	39	Both Sexes	
Gerlack & Gayat	42	Both Sexes	
Arlt	36	Both Sexes	
Lushka	50	Both Sexes	
LeGrange & Tillaux	40	Both Sexes	
Benadikt	39	Both Sexes	
Ricket	40-46	Both Sexes	
Dwight	36-50		
Weiss	39.7		
Merkel	40-5	40 Female	

HEIGHT

Emmett, Baker	34	33.6	29.2
DeWeker, Tillaux	35	Both Sexes	
Vieroldt, Benedict	33	Both Sexes	
Arlt	30	Both Sexes	
Gayat	36	Both Sexes	
LaGrange	35	Both Sexes	
Ricket, Lushka	40	Both Sexes	
Weiss, Gerlach	35	Both Sexes	
Merkel	35	34.5 Female	
Dwight	30 to 40		
Emmert, Lateral Margin Distances	99.7	96	80.8

Broca chose the Dacryon Point 1875
Topinard, the Ant. Lacrimal Crest 1885
Flower, the upper end Post. Lacrimal Crest..1907

Emmert medial wall Male	41.4	Apical and margin points not stated	
medial wall Female	40.3	Children 36	
Gayat 56 skulls	50.6	to Ant. Tip of fovea trochlearis	
56 skulls	47.4	to Crest Lacrimal Bone no apica-pical point—	
Broca roof	50.9		indefinite
Zanda & Geisler roof	53.		indefinite
Testut, DeWeckler roof	43	to central margin	indefinite
roof	40 - 41	medial margin	indefinite
roof	43	lateral margin	indefinite

Emmert	lateral wall	Male	46 - 4		indefinite
Emmert	lateral wall	Female	46	Children 39.4	indefinite
Gayat	lateral wall		48.2	to zygomat-frontal suture	indefinite
Gayat	floor		49.1	to zygo-max. sutura	indefinite
Testut, DeWeckler	floor		46.	to center	indefinite
LeGrange, Zander, Geisler			53.	from optic foramen	to margin
LeGrange, Zander, Geisler			47.	from optic medial angle	to margin
LeGrange, Zander, Geisler			56	from optic lateral angle	to margin
Merkel, depth central			39	43 in males 40.5 females from one part of Germany, other measurements up to 50 mm.	
Richet, Tillaux, central			50		
Emmert, central		Male	39.8	to center of breadth	(which one?)
		Female	39.4	Children 34.75	(which one?)
Merkel central			39	where breadth and height cross	(?)
Arlt central			42		(?)
Gerlack central			43		
LeGrange & DeWeckler			40 - 50		(?)

Table Orbits.

KOENIGSTIENS—Table of measurements or orbits at different known ages; The posterior beginning of the measurements are not definite, nor is there a central anterior measurement which I have regarded as important. The width is to Flowers Point. This is a distinctly interesting table, indicating the quick changes that occur in orbits in the early years, at which time the beginning deviations from emetropia are established.

Age	Height	Width	Intra Orbital Height	Roof	Floor	Lateral Wall	Medial Wall	Right Orbit Obliques
6½ mo.	15	16	17	23	19	20	16	19x15
8 mo.	17	22	23	23	10	9	10	23x19
Birth	18	21	22	32	25	27	22	22x19
1½ yr.	30	32	33	46	40	38	36	33x31
3 yrs.	28	32	32	42	38	37	33	35x27
4½ yr.	28	29	30	41	41	36	37	33x30
5 yrs.	30	33	33	43	42	41	35	35x30
6 yrs.	29	32	32	47	47	44	38	33x39
7 yrs.	30	33	35	46	46	42	39	36x32
12 yrs.	33	34	34	45	39	38	34	40x34
16 yrs.	37	38	38	51	43	45	39	42x35
19 yrs.	34	36	38	51	49	46	40	40x33
22 yrs.	36	37	38	48	45	43	39	41x35

CHAPTER VIII.

The Eyelids.

The Palpebrae (Eyelids), are originally folds of the ectoderm which advance and cover the eyeball, becoming adherent, at about the third month, by their conjunctival tissue only, and at about the sixth month again separating.

The two muscles which are indirectly connected with the eye, anteriorly, and which assist in optical expression, should be con-

M. ORBICULARIS OCULI AND M. CORRUGATOR SUPERCILIARIS.

The palpebral portion of the orbicularis is more delicate in structure and not so intensely red.

sidered as extra-orbital accessory eye muscles; these are the Frontalis, and the Corrugator Superciliaris.

The Frontalis is a thin muscle, on the facial aspect of the forehead, with its fibers running vertically. The fibers attached to the orbicularis, the integument, and fascias of the eyebrows, are the only ones in which we are interested. This muscle has no bony attachments, but is inserted in the above tissues; it raises the brows, and causes transverse lines to appear on the forehead when we look up or when we register surprise.

The Corrugator Superciliaris muscle is a small triangular muscle, that lies under the orbicularis oculi. It arises at the

lower border of the medial end of the superciliary arch, and is directed upward and lateralward, so that its action is downward and medialward. It is inserted into the skin and fascias of the brows, and is the muscle used in frowning or in strained accommodation.

The skin and fascias of these muscular areas belong in fact to the scalp, and are generally described and considered with that anatomy. The palpebrae proper are covered with skin, which has some distinctive features. It is the thinnest in the human body, so that it may be folded and stretched with ease. It has numerous fine hair follicles on its anterior surface. The color of the skin does not materially differ from the surrounding skin in health; there is however, a normal pigmentary deposit in the lower lid, which may be much increased by ill health. The skin of the lids is loosely attached to the underlying tissues; so that the skin is easily shifted away from its usual position. In these tissues there is an absence of fat cells. The pigmentary deposit is quite noticeable after a skin graft to this region, when invariably the new skin is lighter in shade. The thinness and lax attachment of the skin of the lids, no doubt, accounts for the venous stasis which occurs, especially in fatigue, making the eyelids appear darker.

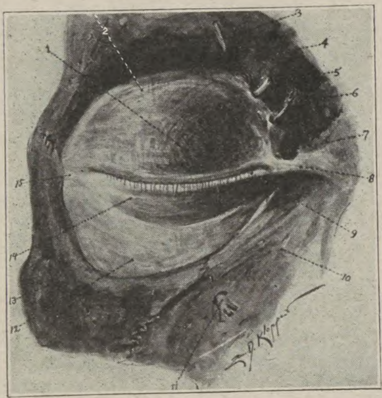
There are several structural folds in the skin of the lids, one especially, the superior palpebral fold, which indicates the insertion of the levator palpebrae superior, the other folds are rudimentary, except in the aged. The inferior palpebral fold is prominent during illness, even at an early age.

Before describing the next underlying structure, the orbicularis muscle, I will describe the foundation of the lids, which is the Fascia Orbito-Palpebralis (Orbital Septum), and its insertional connections.

This fascia (orbital septum) is a continuation of the orbital periosteum into the lids. Its connection at the margo orbitae is not to be differentiated from the periosteum, which is tightly adherent at the margin, so that extravasations are kept from entering or leaving the orbit. It bridges over the incisura superorbitalis, converting that into a foramen. When it reaches the

position of the mid-point of the saccus lacramalis, it leaves the posterior lacrimal crest, to appear on the anterior lacrimal crest, and continue around the margo orbitae. This septum is inserted at the superior edge of the superior tarsus, and at the lower edge of the inferior tarsus. The median insertion of the superior tendon is, however, blended with the tendon of the levator palpebrae superior.

The Tarsus (Tarsal Cartilage) is a fibrous compact connective tissue plaque, which serves primarily to preserve the shape of



FOUNDATION OF EYELID.

(1) Superior tarsal cartilage. (2) Superior palpebrae fascia. (3) Supra orbital nerve. (4) Superciliary arch. (5) Supra trochlear nerve. (6) Infra trochlear nerve. (7) Lacrimal fossa. (8) Medial palpebral raphe. (9) Palpebral fissure. (10) Maxilla. (11) Infra orbital nerve. (12) Inferior palpebral fascia. (18) Malar bone. (14) Inferior tarsal cartilage. (15) External palpebral raphe.

the lid. These plates are distinctive in that their general appearance would lead one to suppose them to consist wholly of cartilage, whereas there is a total absence of cartilaginous cells. The tarsi are inserted, on each medial and lateral side, respectively, into the raphe palpebralis medialis and the raphe palpebralis lateralis, and these in turn are inserted medialwards, into the surface of the processus frontalis of the maxilla, in front of the crista lacrimalis anterior, while lateralward the insertion is into the

tubercle laterale zygomaticum, and extends from the medial angle of the eye to the lateral margin of the orbit.

The shape of the superior tarsus is that of a letter "D" with the rounded border upward, about 10 mm. wide at the mid-point, while that of the inferior tarsus is like a narrow ribbon, about 5 mm. wide.

The raphe palpebralis medialis is not only attached to the anterior lacrimal crest, but is spread above and over the fossa lacrimalis, to form a meager covering for the apex of the lacrimal sac, so that its inferior edges marks about the center of the sac, while laterally it sends a filament around the sac, to blend with the fibres of Horner's Muscle, or that part of the orbicularis oculi which is reflected around to the posterior lacrimal crest. The marking of the lower edge of the raphe lacrimalis medialis is an important one in pathologic conditions of the sac.

The tarsi are rather well-marked plates, in whose connective tissue, at the dependent edges, are the openings of the Meibomian Glands, which are long sebaceous glands with many lateral offshoots; the glands are longer in the mid-positions of the tarsus than at the extremities. In the superior tarsus they number about 30, while in the inferior tarsus there are about 25. These glands are lined with cuboid epithelium, which, like all conjunctival epithelium, becomes stratified near the orifices. They seem to occupy more of the space of the tarsus than does the connective tissue, and are easily observed on everting the lids, as they occupy the middle of the tissue space of the tarsus. Their removal or evacuation requires that the tarsal tissue be cut into. The secretion of the Meibomian glands is an oily lubricant, which prevents the lids from sticking together, and also prevents the tears from overflowing the lids.

Anterior to the tarsus are found the muscles of the lids, the largest of which is the Orbicularis Oculi.

The orbicularis oculi arises from the anterior external surface of the junction of the processus maxillaris ossis frontalis and the processus frontalis ossis maxillaris, externally and across the raphe palpebralis medialis. This muscle is an elliptical sphincter

muscle, and for descriptive purposes is divided into two portions, each of which has a distinctive function.

The Pars Orbitalis is the larger, coarse-fibered portion, which blends with the muscles of the forehead (the frontalis and the corrugator superciliaris), and also with the muscles of the cheek. This portion of the muscle is almost entirely voluntary in action, and comes into play on voluntary closure of the lids, or when shielding the eye from extreme light, beside being one of the much-used muscles in registering various emotions.

The Pars Palpebralis, having the thinner and finer fibres, is the sphincter muscle of the eyelids, and while perhaps sending a few fasciculi to the external raphe, has only an attachment to the lids proper, so that contraction of this part of the muscle draws both lids together and inwardly. This portion of the corrugator muscle is supplied with nerves from the involuntary nervous system as well as the voluntary; it is the muscle used in involuntary winking, while it may be used voluntarily in the firm closing of the eyes.

The Pars Tarsalis is a small offshoot of this muscle, about 6 mm. long, reaching back from the orbicularis as it crosses the lacrimal sac, in front of its lateral aspect, to be inserted into the posterior lacrimal crest. Some of these fibres cross, and are inserted diagonally across each other, so that the fibers from the superior outer edge of the raphe are inserted below the inferior raphe border; therefore, on opening or closing the lids, the superior tarsal insertion of the pars orbicularis will make a traction, or loosen the fibers going around the free unconfined border of the sac, thereby making pressure on, and releasing, the lumen of the sac.

In other words, its action is to assist in closing the eyelids and to widen the tear sac.

The Pars Ciliaris is that portion which is at the margin of the lids, partly in front and partly behind the tarsal plates. These are very pale fibers, but can be readily made out on cross section. This muscle is sometimes referred to as the muscle of Riolan, and is supplied with voluntary as well as involuntary nerve fibers.

There is a layer of unstriped smooth muscular fibers in each eyelid, the upper layer being the better developed and about 10 mm. long. This muscle arises from the inferior surface of the levator palpebrae superior, and is inserted into the superior edge of the superior tarsus; while the lower layer arises from the fascia, near the inferior oblique, and is inserted into the inferior margin of the inferior tarus. These muscles are known as the Musculi Tarsales, Superior and Inferior, or the muscles of Heinrich Müller. They are supplied solely by the sympathetic. They have some action in ordinary winking, especially the lower fibers, which assist in imparting to the lower lid the slight movement which it makes.

The outer attachment of the levator palpebrae superior will be described here, because this is an integral part of the lids. This muscle is attached into the skin of the lids, into the muscle fibers of the orbicularis oculi, the fascias surrounding these muscles, and the superior edge of the superior tarsus, giving off lateral fasciculi to be inserted into the tendons of the canthi. The tarsus attachment is about 8 mm. long and 0.5 mm. thick.

In among the muscular fibers, also, anteriorly and posteriorly, is found the loose connective tissue of the lids, which forms the matrix, allowing free movement of the muscles, skin, and fibrous tissues. This loose connective tissue is devoid of fat cells, while in its substance at the free edge are found the glands and follicles for the lashes.

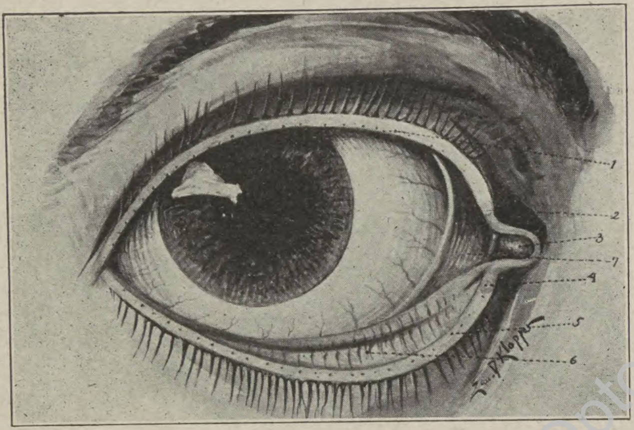
The Conjunctiva Tarsi (Tarsal Conjunctiva) is the thickest portion of the conjunctiva, and is so tightly adherent to the tarsus that when its continuity is interrupted it cannot be stretched across the opening by a suture.

This portion is noticeably more vascularized than the other parts of the membrane, and this superficial vascularity is readily accessible for determining the presence of anemia.

This structure is adenoid in character, which obviously lends itself to certain forms of infections and inflammations. At the superior palpebral portion, and in the fornix, may be found many small acinous glands, known as Krause's Glands, which are

supposed to be accessory lacrimal glands. The epithelium of this conjunctival portion is columnar in character. We will revert to these glands when describing the conjunctiva as a whole.

At the lid margins the skin takes on a transitional change, where it cannot be accounted either skin or mucous membrane, but, like the lips, shows some characteristics of each. The margin may be divided into a medial one-sixth, and a lateralward five-sixths, or better, the medial portion is the lacrimal region, while the outer is the ciliary region. The margin regions are again



SCHEMATIC DRAWING SHOWING LID.

(1) Meibomian orifices. (2) Lacrimal papilla. (3) Lacus lacrimalis and lacrimal caruncle. (4) Lacrimal papilla. (5) Meibomian ducts. (6) Meibomian glands. (7) Plica semilunaris.

divided into two septa, one, the inner, which is flat and which we described as containing the orifices of the Meibomian or tarsal glands, and the outer, which contain the cilia or eyelashes. This anterior part of the septum is somewhat rounded, and the cilia are arranged into two or more rows along its anterior curved border at a line bordering the skin ending. The upper lashes are longer than the lower, and number about 125, while the lower number about 60; each hair is set about 2 mm. deep, and the longest of them are found toward the mid-point of the ciliary region. These hairs are thought by some authors to be the most

sensititive of any on the whole body; they curve in opposite directions from each other, and are readily reproduced on account of their deep-set follicles. Attached to each hair follicle are additional sebaceous glands, known as the glands of Zeiss, and emptying into these, or into the adjacent skin, are the modified sweat-glands known as the glands of Moll.

On approaching the lacrimal region the cilia becomes shorter and more scattered, while they are entirely absent at this region, also the edges of the lids become more rounded around the lacus lacrimalis. The lashes of the lower lid are further away from the edge on the medial lower border than on the lateral lower border.

The blood supply of the lids is mainly through the internal and external palpebral arteries; the former is derived directly from the ophthalmic artery, the latter from its branch, the lacrimal artery. The internal palpebral divides into two vessels, the inferior and superior, one for each lid, which they reach by piercing the free border of the lid, one just above and the other below the medial raphe palpebralis, and form the so-called tarsal arches; on the lateral ward side, they anastomose with the lateral palpebral arteries, which are derived from the lacrimal.

In the superior or upper lid, there is an arch formed by the arteria palpebralis superior, which travels along the superior edge of the tarsus, in among the muscular fibers. These arteries all send branches to each other, to the conjunctiva, and to the skin, supplying the glands in the conjunctiva and the Meibomian glands.

The veins are divided into an anterior set and a posterior set; the anterior empty into the superficial temporal and facial vein, while the posterior tarsal empty into the ophthalmic veins.

The Lymphatics of the lids, like the veins, are disposed of front and back of the tarsus. The anterior empty into the submaxillary glands, while the posterior empty into the pre-auricular and parotid plexus.

The nerve supply of the lids comprises the third, to the levator palpebrae superior, and the facial to the orbicularis palpebrarum, while the sympathetic supplies the involuntary muscles of the lids.

In each lid, near its edge, is found the marginal plexus of Mises, which supplies the hair follicles and surrounding parts, and which may be the explanation of the highly sensitive development of the eyelashes.

The sensory nerves are derived from branches of the supra-orbital and the infra-orbital, of which, on the medialward side, the supra and infra trochlear branches reach the surface and adjacent lacrimal apparatus, while lateralwards the auricular temporal sends some branches to the upper lids. These are all branches of the tri-facial or fifth, and the distribution is generally in front of the tarsus, and behind the orbicularis oculi, where they send branches forward and backward.

The measurement of the palpebral opening, in adults, is about 28 mm. wide, while the height is about half that. The outer canthus is about 4 mm. higher than the inner. The outer canthus lies against the eyeball; the inner is about 6 mm. away from the eyeball. The eye lids, normally, on being opened, cover about 3 or 4 mm. of the upper part of the cornea, while the lower lid just misses its lower edge. These latter figures are quite variable.

The lower lid has no specific levator muscle, and the slight downward movement that it has is the result of falling by its own weight; it is much thicker than the upper lid.

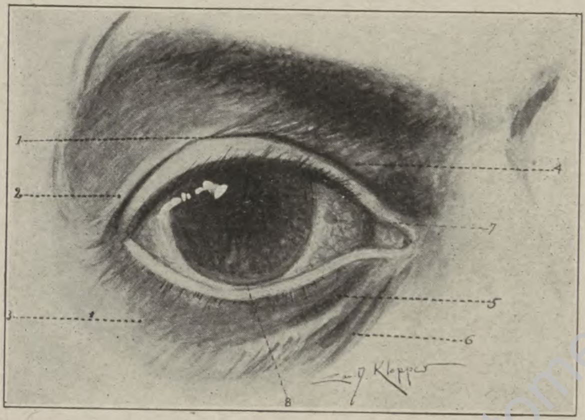
Perhaps this slight downward movement is assisted by the musculus tarsalis inferior, and the fasciculi of the inferior rectus, as both superior and inferior recti muscles send fasciculi to their tendinous sheaths, which in turn are attached by fasciculi to the fibrous tissue of both the lids. It follows that operations for alteration in the length of these muscles will have some effect on the support of the lids.

The external commissure shows an overlapping of the integument of the superior over the inferior portion, so that the pointed angle thus formed inclines somewhat obliquely downward and outward, while the inner canthus is rounded.

The lax underlying connective tissue of the lids allows for extensive swelling (oedema), of the lids, which is prevented from

going around the lid margins by the firmer skin attachment to the cartilaginous tarsus at that point.

In ordinary winking, the lids do not come tightly together, but simply carry the tears over the anterior surface of the cornea, while in forced winking the lids come into perfect apposition, so that the tears are prevented from overflowing onto the face when the lids are forcibly closed. In sleep the upper lid entirely covers the cornea.



EYE.

SHOWING AGE CHANGES AND ATONIC CONDITION OF BOTH UPPER AND LOWER LID.

(1) Superior palpebral fold. (2) Lateral cover fold "pli de recöuvrement." (3) Zygomatic fold. (4) Palpebral hernia "Bourrelet Senile." (5) Inferior palpebral fold. (6) Naso-jugal furrows. (7) Position of pinguecula (8) Early indication of arcus senilis.

On everting the lids the Meibomian glands will be noted by the vertical yellowish lines, while the orifices are the single row of openings near the posterior border of the edge of the lids. The connective tissue layer, in which the muscles lie, allows the splitting of the lids anterior to the tarsus, a fact which is often of value in operations. The reason for the extravasations in the lid parenchyma not traveling into the surrounding skin tissues, is that the superstructure of the surrounding skin is firmer, being filled with fat globules.

The aged show a marked sagging in the skin of the lids, accounted for by the loss of the elasticity of the skin and of its muscular supports.

When the muscles of the lids congenitally undergo defective development, the lids sag, a condition known as Ptosis.

Lids in the Aged.

*The lids are continuous into the neighboring skin without a distinct showing of any particular line of demarcation, however there occurs in later life, on account of the difference in the fat deposit in the one and the lack of it in the other, and on account of the difference that these two contiguous areas show from the various extravasations and atrophies of the muscular constituents, a thin, well-marked line delineating the lid periphery. This line is very noticeable in the lower lid, which from its natural weight may seem lower than in youth. These conditions vary according to the relational bony anatomy and the muscular development.

The upper lid shows, besides the ordinary folds, an overlapping or drooping of the lateral end, composed of sagging skin (called *deckfalte*) while medially it may show a similar condition, and generally accompanied at that position by an extrusion of some orbital fat, into the tissues of the atonic palpebral muscles. (Bourrelet).

Below, there may occur a companion atonic condition of the muscles, that is better brought out during laughter, showing a concentric number of lines converging toward the inner canthus. These may be accompanied by a well marked line in the lid periphery and so cause the lids to appear wider than normal.

CHAPTER IX.

Conjunctiva and Lacrimal Apparatus.

The Tunica Conjunctiva is the mucous membrane lining the lids and covering the anterior one-third of the globe as a continuous layer. Up to the sixth month of life it forms a closed sac, after which it is open in front, at the palpebral fissure.

The tarsal portion, which I have partly described in connection with the lids, constitutes the adherent palpebral conjunctiva (Tunica Conjunctivae Palpebralis). There is an additional folded condition of that portion yet to be described. These folds are in the transitional portion, which is situated near where this part is reflected around to the bulbar conjunctiva, into the so-called fornix. They have been definitely demonstrated to be more folds, and not mucous glands, as described by some.

The Fornix Conjunctivae, is that portion reflected from the lids to the globe, and forms the periphery of the Cul-de-Sac. This is a variable-sized sac, as it dips deeper in some directions than in others. While its lax attachment to the underlying structures allows free movements of the eyeball, this permits also extravasations to travel in this tissue; moreover, when this mucous membrane is compressed or stretched, its elasticity and smooth mucous surfaces allow it to resume its normal position. This portion of the conjunctiva, like the lids and the skin covering them, is interspersed by fine fibrillae of connective tissue and involuntary muscular fibres. The fibrillae are the offshoots of Tenon's fascia (which are found throughout the orbit), connecting the muscles to the sheaths and the sheaths to the various surrounding structures, so that when a muscle or group of muscles acts in any one direction the conjunctiva, skin, and fascias of that side all move simultaneously, which harmonious movement it is highly important to preserve. This interdependence, therefore, should be carefully weighed when operations about the orbit are contemplated.

The Conjunctiva Bulbae is that portion which is reflected on to the eyeball. This is the thinnest portion of the conjunctiva, and is continuous over the cornea, except that only the epithelium is continued onto the cornea. This was described when the cornea

was discussed. It suffices only to emphasize, here, that being a contiguous identical structure, metastatic pathological changes are to be looked for.

That portion of the conjunctiva bulbae which is covering, not the cornea, but the exposed sclera, is known as the Conjunctiva Sclerae. It is attached thereto by the conjunctival substructure (tunica propria) known here as the episcleral tissue. This conjunctiva is so thin, and its attachment so loose, that it can be readily moved around over the underlying sclera. At the limbus, however, it becomes adherent to the scleral tissue.

The epithelium of the conjunctiva is everywhere (except on the cornea), laid on a membranous base known as the Tunica Propria, a semi-elastic connective tissue, which may be tightly or loosely adherent to the underlying structures.

The epithelium of the conjunctiva is of the laminated Columnar type with the larger cells at the base. These cells are continued into the acinous glands of Krause, and also into the lacimal ducts. Perhaps their columnar shape (like goblet cells) is the reason that the folds in the region of the fornix were considered glands, as described by Henle.

The conjunctiva sclerae is more of a pavement variety, with the upper layers flattened considerably; this scleral conjunctival portion contains no glands.

The blood supply of the conjunctiva tarsi is derived from the arcus palpebralis, external and internal, which are branches of the lacrimal and nasal, and these in turn are end branches of the opthalmic. The superior arch sends branches around through the fornix to supply the conjunctiva there, and anastomose with the branches from the anterior ciliary arteries, which are given off from each rectus muscle and supply the episclera and conjunctiva sclerae. The anastomosis of these two systems, at about 3 mm. away from the cornea, forms a vascular marginal network around the cornea. The anterior ciliary arteries, before giving off the branches to the episcleral network, send branches directly into the scleral tissue to anastomose with the arteriosus iridis major. These are in reality end branches of the opthalmic artery. (These facts

are important when considering the blood supply from a compensatory standpoint.) The episcleral network is divided into two planes, one superficial, which is perhaps more finely divided and denser, and called the conjunctival vessels; the deeper portion, known as the episcleral portion, comprising larger vessels not so densely packed.

The conjunctival portion, like the superficial layer of the conjunctiva, is freely movable with that layer, and when congested the vascular meshes are vivid; the inflammation is said to fade away from the limbus, and is characteristic of acute conjunctivitis.

The episcleral portion, which is numerically less, does not, of course, move with the conjuctiva, as these vessels underly the episcleral tissue; these, on congestion, are more pink, ill-defined, and fade toward the limbus; when the congestion is known as ciliary, the pink takes on a violet coloration, and the individual vessels are not well defined.

The close anastomosis of each system emphasizes the importance of relieving these congestions as soon as possible.

The veins of the conjunctiva follow the arteries very closely and finally end in the opthalmic veins. It might be added that the veins of the conjunctiva sclerae take care of the outflow from Schlemms' Canal.

The nerve supply of the conjunctiva (except the corneal section, whose nerve supply was explained to be branches of the ciliary nerves) is from the lacrimal and the naso-ciliary nerves, which in turn are branches of the opthalmic divisions of the trifacial.

In people much exposed to wind and severe weather, and in the aged, there occurs a yellowish, degenerative fat-like deposit, known as Pingueculae, at the horizontal sides of the cornea, in the scleral conjunctiva. These are more or less pigmented, and ordinarily, are not of pathological importance, but when grown into a Pterygium are rather hard to extirpate. Fuchs says, and probably correctly, that "pingueculae are hypertrophied elastic fibrous tissue."

Upper Lid

(1) Superior palpebral fold. (2) Fibers of levator palpebrae. (3) Muscle bundles of orbicularis oculi. (4) Hair follicles with sebaceous follicles. (5) Eye lashes showing the large sebaceous glands. (6) Palpebral fascia. (7) & (8) Muscle of Riolan. (9) Meibomian glands. (10) & (11) Vessels of lower arch of lid. (12) Tarsal plate. (13) Folds of mucous membrane. (14) Attachment of orbital fascia to upper edge of tarsal plate. (15) Krause's glands or folds of mucous membrane. (16) Fornix. (17) Accessory lacrimal glands. (18) Orbital fascia. (19) Involuntary muscle. (20) Tendon of levator palpebrae superior. (21) Fat in tissues above the lid.

The conjunctiva is more or less pigmented, especially in the darker races.

Lacrimal Gland.

The conjunctiva, besides being pierced by the 15 to 20 glandular openings of Krauses glands, which are placed around the fornix, mostly superiorly and medialward, is pierced lateralward and

LACRIMAL APPARATUS.

Showing position of accessory or Krause's glands, also the two lobes of Lacrimal gland.

superiorly by 8 to 10 ducts, or openings, of the Glandula Lacrimalis.

The Lacrimal Gland is situated in the fossa glandulae lacrimalis, surrounded by a mass of orbital fat. It is an acinous, tubular gland, with short tubules, surmounted by rounded lobules measuring about 1 mm. in diameter. The tubules so intersect that they finally form quite large vessels, and the ducts of the superior lobe frequently empty into those of the lower lobe, or near them.

These glands are lined with a cylindrical goblet epithelium,

and, like the salivary glands, are controlled by the sympathetic nerves.

The lacrimal gland is partly divided by the outer horn of the anterior tendon of the levator palpebrae superioris, which partial division causes the two portions to be called superior and inferior glands or lobes. This division is not justified on anatomical grounds, as the gland is simply rolled around this tendinous insertion of the levator palpebrae superior, and molded into this situation during the course of development. There is a connective tissue structure in between the tubules, which, collecting on the surface, forms a slightly marked thin capsule, with trabeculae to the periorbita and Tenons' sheath; these trabeculae have been variously described as suspensory ligaments, but are hard to demonstrate, and very irregularly placed.

The lacrimal gland appears, on dissection, to be a somewhat flattened ovoid mass, slightly pinker than the surrounding yellow orbital fat, measuring about 20 mm. long by 10 mm. broad, and weighing about 0.75 grams (12 grains). The female is supposed to have better developed lacrimal glands than the male, perhaps on account of the more room in the fossae lacrimalis, due to the overhanging walls being not so thick and the eyeball somewhat smaller.

The tears are secreted not only by the lacrimal gland, but by the conjunctival glands, and it is supposed that no more tears are ordinarily secreted than can be disposed of by ordinary evaporation.

Destruction of the gland itself is not necessarily followed by a dry eye, as the accessory glands can provide for the ordinary moistening of the eyeball.

The lacrimal artery, from the opthalmic, supplies this gland, while the veins empty into the superior opthalmic vein.

The nerves are: the lacrimal branch of the opthalmic division of the trifacial, and the sympathetic system from the carotid plexus.

The cerebral excito-secretion fibres are said to be derived, in

a round-about way, from the seventh to the fifth, through the greater superficial petrosal to the spheno-palatine ganglion.

Lacrimal Passages.

The conjunctiva at the inner canthus covers the horseshoe-shaped Lacus Lacrimalis, which dips down slightly at the medial angle. It also shows, at the lateralward side of this lacus, a fold, which begins some distance away from the exposed area, so that from the gradual increase of the tissue of the fold it may be followed to two pointed horns, which lose themselves in the surface of the medial conjunctiva of the superior and inferior fornices which summit is at the lateral side of the lacus lacrimalis. This is known as the Plica Semilunaris. This plica is supposed to be the morphological remains of the third eyelid, and is better developed in some races than in others. It undergoes about the same degeneration that occurs in the pinguecula.

The Caruncula Lacrimalis is in the center, and lies on the mucous membrane of the lacus lacrimalis. It is a small, somewhat red elevation, horizontally oblong, which almost fills up this depression. It is in reality a portion of skin, which is separated from the lid margin, partly changed by its new environment to a mucoid consistency, although retaining its epithelial structure, as shown by the presence of connective tissue and fat, with hairs and sebaceous glands intermingled. Sometimes, these hairs are so numerous and long that their removal is necessary, while the sebaceous glands secrete the white deposit found in that portion of the eye.

The conjunctiva at the Ductus Lacrimalis takes on a stratified pavement epithelial character, similar to the scleral portion, while the saccus lacrimalis and the ductus naso-lacrimalis are lined with a double row of columnar epithelium. The lower area of the epithelium of the ductus naso-lacrimalis is perhaps somewhat ciliated, especially near the transitional point of this conjunctiva, where it merges into the nasal mucous membrane.

There are several loose folds in the mucous membrane of the canaliculi and ducts which have been variously described as valves. As many as 12 to 14 different authors have given their names to

these folds as valves. However, the lack of any regular definite form of any of these so-called valves raises a doubt as to their existence as such.

The continuity of this conjunctiva into the nasal cavity accounts for the direct inflammation extensions from the nasal cavity. The sub-mucosa, in the lacrimal passage conjunctiva, is thick and mixed with the fibrous offshoots which are sent into it from the septum orbitalis. When passing over the upper part of the saccus lacrimalis from the posterior lacrimal crest to the anterior lacrimal crest, the septum orbitalis, like all tendons that leave periosteum, is incorporated into the periosteum, and cannot be differentiated from it, so that the periosteum covering the medial side of the naso-lacrimal canal is exactly the same fibrous tissue that the reflected anterior portion of the septum orbitalis is, and not a split portion of it. When the septum orbitalis passes over to the anterior crest it is punctured by the two canaliculi, to which it (the septum) sends longitudinal fibrous fibers to reinforce the walls of the canaliculi, while the periosteum of the canal, especially the lower portion, becomes so incorporated with the saccus naso-lacrimalis that the two cannot be separated, nor is the lower portion of the sac extension to be differentiated from the naso-mucosa. This fibrous intermingling is extended up throughout the sub-mucosa of the saccus lacrimalis to its apex, although the apical portion is not adherent to the walls.

The beginning of the excretory lacrimal passages is at the Punctum Lacrimale (called Puncta); they are minute openings in the center of the Papillae Lacrimalis. The papillae are placed on the post-tarsal borders, at the medialward end of the lids, about 6 mm. away from the medial canthus; the lower puncta is perhaps 0.5 mm. further removed lateralward. These puncta are directed backward on the closure of the lids, pulled in that direction by the action of the pars lacrimalis, whereas, when the lids are open, they are in a more vertical plane; when directed backward they lie well into the lacus lacrimalis. These puncta are important in their minuteness, the ocular end being somewhat open, which soon is converted into a capillary tube, which capillarity furnishes the suc-

tion power which first draws the tears away from the lacus lacrimalis into the caniculi.

The height of the vertical portion of the Canaliculus (Ductus Lacrimalis) is about 2 mm. which is important to remember, when introducing a probe. The tissue around these canals is heavily reinforced with a ring of fibrous tissue and elastic tissue, and when this tissue is stretched the canal does not regain its normal capillarity. The horizontal portion is about 8 mm. long, and is quite large in lumen as compared with the vertical portion; the lower canal is a little larger than the upper. The lumen is normally about 0.5 mm. diameter but it may be dilated to nearly four times its normal lumen; it is not well, however, to over-distend them.

The reflection of the septum orbitale over the saccus lacrimalis is called the Fascia Lacrimalis. The ducts pierce this fascia separately, and at the same time receive some of the fascial fibrous filaments into their own walls so as to strengthen them. After piercing the fascia lacrimalis, the canaliculi enter the saccus lacrimalis, sometimes separately, but usually by a common opening immediately behind the mid-section of the ligamentum palpebrale mediale about 1 mm. deeper than its anterior surface.

The Saccus Lacrimalis (Sac) is that portion of the lacrimal apparatus which lies above the plane of the inferior wall of the orbit; while extraorbital in one sense, yet it is called the orbital portion of the canalis naso-lacrimalis.

This sac lies in the fossa lacrimalis, and its medial side is curved like the medialward side of that fossa, into which it snugly fits, while its lateral side is flattened on an angle, with the apex upward, the lower thicker portion of the angle meeting the rounded inter-osseous portion which starts at the inferior wall of the orbit. This lower portion is known as the maxillary portion, while its nasal opening is referred to as the meatal opening.

The Sac is pierced by a canaliculus about 5 mm. below its apex, and from that position upward, or rather from the inferior edge of the raphe palpebralis medialis, is enclosed by the fascia orbitalis and the pars lacrimalis. Not only does the raphe palpebralis

medialis cross the middle of the sac, but it is rather spread out over the upper sac, in its anterior periosteal connections, in a fan-shaped manner. Horner's muscle is almost entirely above this lower margin of the raphe, while below the raphe the sac is only covered by skin, orbicularis muscle, and fascia lacrimalis. The sac is about 12 mm. long and about half that broad at its base, or lower end, whence it is wedge-shaped to its apex, so that at the entrance of the canaliculus it is about 3 mm. broad, while its inter-maxillary portion is about 25 mm. to its meatal opening. These measurements are obviously very variable. The sac and duct being subject to many infoldings and twists, the lumen necessarily differs widely all along its course, generally averaging about 3.5 mm. throughout.

Perhaps some statement as to the meatal opening and its position in the nose would be in place. It opens usually in the inferior meatus, but whether as a grooved, round, flat, or other variety of opening, it would be hard to say; it is rather described as variable.

The flow of the tears through the lacrimal passages is accomplished first by the capillary attraction of the puncta, which, being immersed in the lacus lacrimalis, draws the tears into the canaliculi. The canaliculi are emptied by the act of winking, whereby the pars lacrimalis is compressed, pulling the sac wall away, and forming a larger lumen there. On opening the eyes, the elasticity of the sac forces the tears in the direction of the least resistance, i. e., toward the nose, forming a vacuum. which draws in more tears into the canaliculi through the puncta.

Luciaini says, "There is, under ordinary conditions, very little fluid entering the lacrimal passages, as it is thought that ordinary evaporation is sufficient for the normal secretion." It has been proven by Shirner (1902), who reported fifty cases of extirpated sac, that the removal of the sac does not necessarily cause an overflow of tears on the lower lid.

Another circumstance which doubtless favors the out-flow of tears through the canaliculi is that the medial palpebral fissure is about 4 to 6 mm. lower than the lateral fissure. The fact that when crying, a person sniffs in air, may act as an additional suction to the excretion of the tears. There is, however, a wide di-

versity of opinion, as to the exact mechanism of the conveying away of the tears from the Lacus Lacrimalis.

Darwin, speaking of weeping in his expression of emotions, says, "That when persons who ought to wear convex glasses, habitually strain the powers of accommodation, an undue secretion of tears follow, and the retina becomes unduly sensitive to light."

CHAPTER X.

Muscles.

The three varieties of muscles met with in the body are regarded from a functional as well as a structural standpoint, namely, the involuntary smooth, non-striated (visceral muscles), the voluntary or striated skeletal muscles, and the striated involuntary muscles of the heart substance.

Involuntary muscle is composed of ordinary cells with all the characteristics of simple mono-nuclear cells, with the shape elongated, forming a sharply pointed muscle cell and the middle expanded portion containing the nucleus. The nucleus also becomes lengthened out (rod-like) and is rounded on the ends. These muscle cells, now called muscle fibers, vary as to length and to size, their length being from 50 μ to 150 μ and their thickness from 5 μ to 8 μ.

The fact that this muscle fiber takes on an acid stain, like eosin, makes it possible to differentiate it from the accompanying connective tissue filaments. There are within the muscle-cells long parallel fibers which may be distinguished, and which on cross section divide the protoplasm into small partitions that appear stippled—bead-like. These long fusiform muscle fibers are each surrounded by a frail network-membrane, known as the *perimysium internum,* which adheres to the cell wall or sarcolemma, so that the two contiguous muscle fibers are separated by a single interposed membrane. Often, when pulled apart this membrane remains adherent to either fiber wall and the adhesions have been described as bridges.

These muscle fibers when in large numbers form the distinct involuntary muscles, which display the cells in a massed formation; while in other situations they may occur sparsely, interspersed with connective tissue, which divides the fibers into single or minute bundles. Almost all the muscular tissue found in the abdominal organs, in the mucous membranes throughout the system, in the blood vessels and in the lymphatics, is of this variety. In the network between the muscle fibers are found the capillaries, lymph vessels and the dendrites (neuroaxis) of the sympathetic

nerves (neurons), which nerve system supplies exclusively this muscle group in all its situations, and these situations are almost universal throughout the body. The heart is an involuntary muscle, but striated; however, there is no portion of the body, even there, without blood vessels, so that we have smooth muscle tissue there also. Especially is this muscle tissue found in the eye, where we have two muscles showing its highest development, viz the iris and the ciliary muscle, and the distribuited varieties in the lacrimal apparatus and the choroid.

The cells of voluntary muscles are striated transversely, whereas we have seen that involuntary muscles are striated longitudinally. These transverse striations divide the muscle up into plate-like cells, where the plasmodium shows that several cells have coalesced without the nuclei joining together, so that there is a syncytium formed, meaning a fusion of cells as regards the protoplasm only. These arise in the ovum from the cell division derived from the primitive myatomes, and as the muscle grows the cells coalesce, but contain the original nuclei of the separate components.

These fibers elongate very materially (may be collected in columns or distributed over wide areas) and are rounded on the ends; where they meet bone or cartilage they occasionally stretch out to 120 mm. The thickness varies according to the coarseness of the muscle, measuring from 10 μ to 100 μ. The ends of these cells, when they meet other muscle fibers, become beveled and are supposed to be united by a cement-like substance. The striated muscles are interspersed with a perimysium internum, which, collecting on the surface, is called a perimysium externum and muscle sheath, the perimysium internum being connected to the muscle cell or cell wall, and there containing the voluntary end (axones) fibers of the supplying nerves, so that the ultimate contractile stimulation of a muscle not only reaches the muscle sheath and the various nerve bundle, but is continued into the primary cell itself (known as the sarcoplasm and its nuclei). Nearly all the nuclei lie at the periphery of these cells, surrounded by the sarcoplasm; some of the longer fibers have hundreds of nuclei.

The greatest significance of this group from a functional construction standpoint lies in the contractile fibers, which appear striated across. However, these bundles may, from a changed position, performing some particular function, appear striated longitudinally. These fibers are known as red or white, a color distinction to denote the content of sarcoplasm, which is deposited in variable quantities.

The muscle, although endowed with distinct properties, may be so placed that its greatest function is in its co-ordination as a part of a group of muscles, and then they are so developed that their nerve and blood supply is often from a common origin or homologous region. This is particularly true of the muscles of the eye, which, developmentally and functionally, must be thought of as a group, so that our study of the physiological action of the musculature of the eye must be of a co-ordination of the two types of muscles, voluntary and involuntary, in the highest degree.

The Orbital Muscles.

The Musculi Oculi, or extrinsic muscles of the eyeball, are named as follows: The Rectus Superior, Rectus Medialis, Rectus Inferior, Rectus Lateralis, Obliquus Superior, Obliquus Inferior, and the Levator Palpebrae Superior (which last is usually counted at least an accessory extrinsic muscle, on account of its close association in its origin, innervation, function, and distribution).

The Levator Palpebrae Superior arises from the oval annulus of Zinn, in a common tendinous insertion with the rectus superioris at the superior side of the annulus of Zinn, which I will presently describe: after its origin at this tendon, it is attached to the periorbita at the superior wall, where its tendinous insertion is in close contact, by fibrous spiculae, which reinforce its insertion. In its course forward it is in close opposition with the rectus superior, the sheaths of the two muscles being adherent along most of their contact points, which contact points extend beyond the equator of the eyeball. Their blood supply and invervation are identical, and from their common origin to the anterior separation, the actions of these muscles are in unison, because not only

do the belly muscle sheaths have an intimate connection, through their fine interwoven trabeculae, but Tenon's fascia is adherent throughout in such fashion that filaments of the superior rectus are physiologically traced into the attachments of the levator, so that the movement of the eyeball upward is followed by tension of the end attachments of the levator superior; conversely, any interference with the power of one muscle affects the power of the other directly.

The anterior end of the levator palpebrae is spread out into a tendinous aponeurosis, which has several places of attachment; the endings usually are in delicate filaments, although the principal aponeurosis divisions can be followed to the superior tarsal border and the lateral and medial canthi.

It sends filaments into the skin and subcutaneous tissue of the upper lid, into the fasciculi of the orbicularis oculi muscle and the deeper stroma of the upper lid, into the superior edge of the tarsus superioris, and into the fibers of the septum orbital, and lastly, but not of least importance, into the conjunctiva of the fornix; while at either end of the tarsus it sends crescentic-like projections to the superior margins of the canthi; so that all of these tissues move harmoniously with the contraction of this muscle.

The crescentic extensions which go to the canthi are continued through the two raphe palpebrales, to their ultimate endings at the margo orbitae, the lateral one very much better developed and more firmly attached, around which curve the lobes of the glandulae lacrimalae.

The attachment of the lateral horn, or extension, into the tubercle laterale is the firmer attachment and somewhat retards the upward movement of the upper lid, as shown by the fact that the greatest excursion of the upper lid is medialward.

The larger lobe of the glandula lacrimalis, unless swollen, cannot be perceptibly palpated, except that under the lateralward attachment of the crescent of the levator palpebralis aponeurosis a small nodule may sometimes be felt, and even seen, to protrude when the lid is everted.

The Ligament of Zinn (Annulus Tendineus Communis) is

a narrow band of fibrous tissue, about 3 mm. broad, which extends around the superior, medial, and inferior border of the foramen opticum, and, swinging across the wider portion of the fissura orbitalis superior, is inserted lateralwards into the "Spina Recti Lateralis" (Tubercle of Zinn), into which this whole ligament of Zinn, as it crosses over to that side, is attached. As you will note, this ligament is a continuous band across this foramen and does not merely go around it; therefore, the apex of the muscular funnel is at this band origin. The fact that this band has reinforcements, anteriorly, into the small bridge of bone that divides the two foramina, does not affect the continuity of the band. There are also posterior extensions, around the periphery of the swinging backward-edges of the fissura orbitalis superior. Just as the levator palpebralis superior and the obliquus superior, at their origin insertions, have additional extensions into the periorbita, to reinforce their attachments, so does this ligament have extensions to the possible adjoining posterior walls. These are to be considered as secondary insertions, and not extensions of muscles beyond their primary ligamentous origin, which primary or main insertions are at this Ligamentum Zinn (Annulus Tendineus Communis).

All of the recti muscles arise at this ligament, which is *not* anatomically divided into two portions, as the tendons of all of the muscles meet and fuse at their origin, while, in addition, the levator palpebrae superior and the obliquus superior have their origin here. So, then, the superior common tendon of the muscular funnel gives passage to the optic nerve, the ophthalmic artery, and sympathetic fibres from the carotid plexus (entering through the optic foramen), the oculomotor division or third nerve (entering laterally through the extension across the superior fissura orbitalis), the abducens or sixth nerve, the naso ciliary branch of the fifth, the sympathetic root of the ganglion ciliaris, and the superior ophthalmic vein. This latter space being about 3 mm. broad, these vessels and nerves necessarily are in close contact here with the optic nerve. This tendinous ring being so intimately interwoven with the periorbita (which is the external extension

of the dura), it is rather difficult to get a definite line of demarcation between the two tissues.

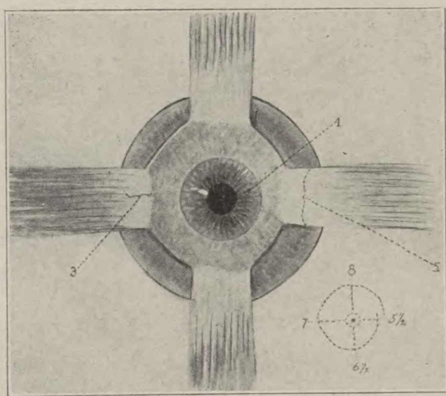
The reason that the ligamentum Zinn was thought to be divided anatomically into two portions, a superior and an inferior, is that no definite line of demarcation was made, either posteriorly or anteriorly, of this muscular funnel, but the place where the muscle tendons anteriorly soonest took on definite, separate entitles was considered the division point for the two so-called segments, as some of the muscles are attached laterally further forward to each other, by interwoven fasiculi, than others. The occasional presence of the anterior reinforcements onto the bridge of bone, between the two foramina, furnishes additional reason for this disputed muscular origin (however, this bridge of bone is often absent).

The weight of each of the recti muscles is about 0.75 gram (12 grains) except the superior rectus which weighs about 0.5 gram (7 grains). The posterior tendons of each of the orbital muscles are about 8 mm. long, while the total length of the recti muscles is about 40 mm. The fact that most anatomists give the length of the lateral rectus as 40 mm. is one of the strong arguments in favor of its arising from a single head, because the extension backward would make this muscle about 8 to 15 mm. longer, depending on where the heads were supposed to stop.

From an anthropological standpoint, the origin of the extrinsic ocular muscles is interesting, for the reason that in the larger apes, like the Chimpanzee, Orangs, and Gorillas, the superior orbital foramen is about the size (maybe 1 mm. larger) of the optic foramen. It does not show, as in man, a long wide channel for this foramen, but the foramen takes more the rounded oblong shape of the optic foramen, with an occasional rudimentary notch, to indicate the position of the narrow superior cleft, so that with the two rounded foramina facing toward each other, it is easy to understand that an annular ligament could span the two rounded openings and form the apex of the cone of the muscles. It is no different in man so far as the attachment is concerned, although there are developments back of this, and anterior to it, which would change the neighboring relations; but the muscle origin is the same

oval annulus, therefore in both man and monkey there is no occasion for two heads of the rectus lateralis.

The Musculus Rectus Superior (Superior Rectus) arises at the superior side of the annulus of Zinn, from a common liga-



ANTERIOR INSERTIONS OF RECTI MUSCLES.

(1) Iris, showing distinct spacing of its limbus away from the muscular insertions, as indicated by explanatory plan. (2) Width of anterior tendons. (3) Length of anterior tendons.

AVERAGE MEASUREMENTS.

Average width of cornea 12 mm.
Average height of cornea 11 mm.
Average width of rectus tendons.
  Int. rectus 10 mm.
  Inf. rectus 10 mm.
  Ext. rectus 9 mm.
  Sup. rectus 10.5 mm.
Average length of tendons.
  Int. rectus 4 mm.
  Inf. rectus 5.5 mm.
  Ext. rectus 9 mm.
  Sup. rectus 6 mm.

Superior oblique is about 10 mm. broad at insertion. Inferior oblique is about the same, not tendinous as a rule, but muscular.

ment with the levator palpebrae superior, and through the adherence of the muscle sheaths of these two muscles, they are united through their whole course, until they meet the equator of the eye, where they begin to diverge from each other; this con-

nection is perhaps firmer medialwards because the levator becomes somewhat wider, on its lateralward side.

The visual axis of the eyeball is situated at an angle of about 23 degrees away from the sagittal plane, so this muscle takes about that angle to its insertion, which, taken together with the fact that its insertion is in front of the equator, and the axis of rotation behind the equator, will account for the action of the muscle not only elevating the eyeball but adducting it at the same time. The same general conditions hold true for the inferior rectus.

The attachment of this muscle at the scleral end is about 7.5 mm. away from the limbus, with a tendon measuring 10.5 mm. broad and about 6 mm. long. The superior division of the oculi motor, or third nerve, supplies this muscle, and also the levator palpebrae superior. Where the superior rectus meets the sclera anteriorly, it not only thickens the sclera at that place, but is fastened by secondary insertions into the sclera, and into Tenon's sheath, which envelopes the muscle. These secondary insertions are sometimes found as far back as the equator, and while inconstant and irregularly placed, they are more or less present in most of the recti muscular attachments. This is the reason that these muscles do not retract far when severed, and also why these secondary fibres must be severed in enucleation. These latter remarks as to the secondary insertions, and the attachments to Tenon's sheath, hold good for all the recti muscles.

The arterial supply of the recti muscles is through branches of the opthalmic, called the anterior ciliary arteries, which pierce the bellies of the recti at about their mid point, internally in relation to the muscular funnel.

The Musculus Rectus Medialis (Medial Rectus), arises from the medialward side of the annulus of Zinn and is inserted into the eyeball about 5.5 mm. back of the limbus, with a tendon about 10 mm. broad and 4 mm. long. It is supplied by the oculo-motor nerve. This muscle, like the lateral rectus, moves the eye only in a horizontal plane. It is the thickest of the recti and has the shortest, widest, and closest-to-the-limbus attachments.

The Musculus Rectus Inferior (Inferior Rectus) arises

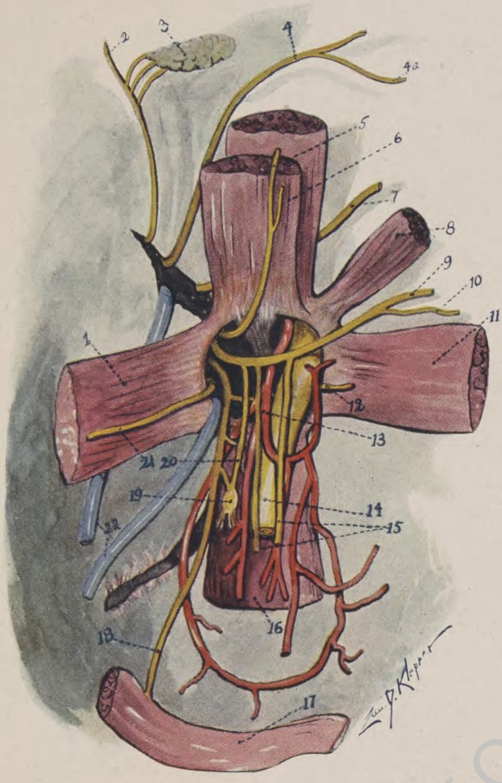
from the inferior border of the annulus of Zinn, and is attached into the sclera by a tendon 6.5 mm. away from the limbus, which tendon is 10 mm. broad, by 5.5 mm. long. This muscle lies somewhat more medialward than the superior rectus. It is supplied by the oculo-motor nerve.

The Musculus Rectus Lateralis (External Rectus) arises from one head, from the lateralward side of the annulus of Zinn, and is inserted into the sclera about 7 mm. away from the limbus with a tendon about 9 mm. broad and 9 mm. long. The nerve supply of this muscle is the sixth, or abducens nerve, and the blood supply from the lacrimal branch of the opthalmic artery.

All the recti muscles arising at the orbital apex are more or less crowded at their origin, but when approaching the globe they leave their close apposition to the walls, and are directed to the globe, which lies a variable distance away from the walls, in the anterior part of the orbit.

The Musculus Obliquus Superior (Superior Oblique) arises from the annulus of Zinn, from between the superior and medialis recti, somewhat posteriorly to the origin of these two muscles. Its tendinous origin is reinforced by posterior fasciculi or tendinous insertions into the adjoining periorbita. This is a more slender muscle than the recti; it passes forward and upward to reach the trochlear pulley, where it becomes fibrous or tendinous. Passing through the pulley, it proceeds downward, lateralwards, and backwards, to be inserted into the eyeball by a tendinous insertion between the superior and lateral recti muscles, back of the equator. The superior oblique is not only attached behind the equator, but this attachment is lower than the pulley, so that the traction is partially from above, as well as from behind and medialwards.

The direction of the tendinous insertion, or the physiological insertion, is at an angle of about 55 degrees from its anterior sagittal plane. The insertion is somewhat fan shaped, about 10.5 mm. broad, and is about 6 to 8 mm. back of the equator. The reflected portion is about 20 mm. long, while the direct portion is about 40 mm.



Origin of Muscular Funnel and the Relational Anatomy at that Position, Looking at it From the Front

(1) External rectus showing its single head. (2) Lacrimal branch of the trifacial. (3) Lacrimal gland. (4) Frontal nerve. Supra-trochlear (5) Superior division of oculo-motor nerve. (6) Superior rectus, with levator palpebrae just above it. (7) Trochlear nerve. (8) Superior oblique. (9) Naso ciliary. (10) Infra-trochlear. (11) Internal rectus. (12) Branch of oculo-motor to rectus medialis. (13) Ophthalamic artery. (14) Optic nerve. (15) Long ciliary nerves. (16) Inferior rectus. (17) Inferior oblique (18) Nerve to inferior oblique. (19) Ciliary ganglion. (20) Long ciliary branch. (21) Abducens nerve. (22) Ophthalmic vein, if in a single root, it generally emerges through the muscular funnel.

This muscle from its pulley origin to its insertion, lies under the rectus superior. Its innervation is through the trochlear or fourth nerve. The reflected portion of this muscle from the entrance into the trochlear pulley to its insertion, is entirely tendinous.

Trochlea.

The *trochlea* (pulley) is situated about 5 mm. behind the superior medial angle of the orbital margin and is composed of a circlet of fibrous cartilage measuring about 5 mm. in diameter and the same in length, through which passes the tendon of the superior oblique muscle. This circlet of cartilaginous fibrous tissue is an offshoot of the periosteum; it is partly imbedded in the trochlear fossa, which sometimes shows an extra spur-like process to receive these extra supports. These same trabeculae are attached to the sheath of the tendon of the oblique muscle, so that while there is a free movement of this tendon through the pulley, yet it is somewhat impeded and prevented from moving too far. The trabeculae are attached also into Tenon's sheath, which encloses and follows the reflected tendon of the muscle from its insertion right up to the trochlea. From a morphological standpoint, this pulley is of interest, from the fact that in many of the vertebrata the superior oblique is a direct muscle which arises in front of the equator, and, as I have stated, sometimes from a common tendon with the inferior oblique. Therefore, to explain the fact that this pulley originated because of the necessity of having the origin of this muscle move to a rear position, there to give this muscle a more advantageous position of origin, and leaving the inferior oblique in its relatively original position, is hardly a sufficient explanation of the deviation from an anthropological standpoint.

There is, as all agree, a posterior development of the orbit, which is shown even in the man as compared with the monkey, but that this would carry one muscle back and leave the other forward is beyond my conception of the probable reason.

The Musculus Obliquus Inferior, (Inferior Oblique), is the only one of the extrinsic ocular muscles that does not arise at the apex of the muscular funnel, but at a depression on the medial

inferior anterior angle of the inferior wall, lateralwards to the upper entrance of the lacrimo-nasal canal. It passes backwards and upwards, underneath the inferior rectus, to which its sheath is attached by a ligamentous attachment, called the suspensory ligament of Lockwood; and is inserted into the sclera, further back of the equator than the superior oblique, between the superior and the lateral recti. It passes between the rectus lateralis and the eyeball. This muscle has no ligamentous attachment but is muscle fiber throughout, the muscle fibers entering directly into the scleral tissue. It lies at an angle of 75 degrees with the orbital axis. Its posterior insertion is about 6 mm. away from the optic nerve entrance, on the foveal side, so that it is inserted almost at the optic axis posteriorly. The inferior oblique lying opposite to the superior oblique pulley, arises lower than its insertion, i. e., diametrically opposite the superior oblique origin, which is higher than its insertion, so that it has a partial downward pull, as well as anteriorly and medially. The inferior oblique measures about 36 mm. long.

The entrance of the oculo-motor nerve, which supplies this muscle, is on its flat posterior border, about its mid-point.

In some animals the rotation of the eyeball is not as great as in man, because in some animals the eye fills up a greater proportional space in the orbital cavity, while in others, like the sheep, the eyes are placed laterally, having an oblong pupil, that does not necessitate much movement; hence there is not as great a development of recti muscles as such a large eye would seem to warrant.

In man and in monkeys, the oblique muscles are inserted posteriorly to the equator, while in all other animals the insertion is anterior to the equator. In a great many animals, the two oblique muscles arise outside the muscular funnel, in front, sometimes at a common origin, so that they have the power, when making traction at the anterior segment of the eyeball, to protrude the eye. In many mammals and amphibions, there is a seventh orbital muscle. It is a cone-shaped muscle, and arises at the apex of the muscular funnel, internal to the recti muscles, and is inserted internal to the recti, into the sclera behind the equator. This is called

the Choanoidens or retractor muscle. Its action is to retract the eyeball, when necessary.

The eyeball does not move from its position but rotates around an axis; where this point of rotation is situated, is a question on which there are various opinions. Fuchs' explanation of the point of rotation is undoubtedly the clearest to understand, and I am indebted to him for this explanation.

The point of rotation given by Brubaker is 1.7 mm. behind the equator, Piersol says 1.5 mm. Fuchs and Whitnall give about the same measurements. I think that the best general measurement for all eyes, whether hypermetropes or myopes, is 10 mm. in front of the fovea. (My own opinion is that it should be about 3 mm. further back, for the reason that the length of the orbital portion optic nerve is only 7 mm. longer than the straight line between its attachments, and its (the nerve's) large size and insertions do not allow undue straining, so that it is inconceivable that it should make the proportionately enormous excursions which are taken by the corneal apex.)

Luciani, Junge, Donders and Doizer show that in emmetropic eyes the center of rotation lies 13.54 mm. behind the summit of the cornea, in hypermetropes 12.32 mm., in myopes 15.86 mm., or an average of 1.3 mm. behind the midpoint.

All the movements of the eyeball can be considered as movements around three primary axes, which are at right angles with each other; the vertical axis, around which are the lateral movements, called abduction and adduction; the tranverse axis, around which are the depression and elevation; and the sagittal axis, which corresponds to the visual axis.

These are primary directions, which may be affected by only the combined action of the muscles working in unison; when one set is contracted the antagonists are extended, but while extended they serve to steady the eye in the position it assumes, so that in all movements of the eyeball we have a combination of all the physiologic efforts of muscular tissues, which are flexion, extension, synergism, and fixation.

The ocular muscles are innervated by comparatively large

direct nerve branches, which might account for the acute control of the muscular mechanism.

The anterior insertions of the recti muscles are as noted, an unequal distance from the corneal margin, and the anterior lines of insertion are set at various angles in their relation to the limbus. The insertion points do not exactly coincide with the vertical and horizontal axes: their action is however controlled by the fact that they work in sets. Another fact which must at all times be kept in mind is that these muscles are all encased by reflected continuations of Tenon's capsule, through which there are fascicular prolongations of fibrous tissue, which not only unite this capsule to the muscular tissue, but unite the various folds of fascia with each other, so that the eye cannot escape from its firm attachment to its synovial sheath; this sheath, therefore, acts as a kind of check ligament to the eyeball, as well as to the muscular action. These ligaments, laterally and medially, are inserted into the raphe palpebrae insertions on their posterior sides. Tenon's fascia not only covers the muscles and their sheaths, but is reflected around the various other elements of the orbit, protects the optic nerve and the sclera as far forward as the limbus. In the intertwinings of Tenon's fascia lies the orbital fat, which serves as a pad for the various separate important structures of the orbits.

The orbital fat is apparently more delicate and more loosely packed around the optic nerve and central tissues than around the peripheral structures.

As in the upper lid, where the levator palpebrae and the rectus superior are united by fascicular tissue, which finally finds its ending in the skin and fascia of the lid, so there occurs in the lower lid a similar condition, that is, fascicular tissue from the rectus inferior is attached finally to the skin, intermuscular tissue, and cartilaginous framework of the lower lid.

Probably the simplest movement of the eye is made possible by the concurrence of all the muscles and tissues of the orbit. Anatomy demonstrates that the eye moves with Tenons capsule and not inside it, as Tenon's capsule is not a synovial sheath such as we have in other parts of the body, that there is a minute move-

ment possible is correct, but its anterior, attachment and its muscular and ligamentous attachments will not let it go far, so that all the orbital contents move together, on its cushions of fat, the greater part of this sheath is attached to the various soft parts rather than being firmly attached in large bundles to the bony walls. This universal attachment plays no small part in steadying the movements of the eye, quite as much perhaps, as the supposedly graduated resistance of the muscles which is as yet not definitely proved.

CHAPTER XI.

Orbital Vessels and Nerves.

The Arteria Ophthalmica (Opthalmic Artery) is a branch that issues from the internal carotid, at its bend, just as it reaches the lower border of the optic nerve, and before this nerve pierces the internal cranial opening of the foramen opticum. The opthalmic artery accompanies the optic nerve through that foramen, being situated on the lower lateral wall of the foramen, and separated from the nerve by the envelope of the dura, which is thrown around both nerve and artery, giving each a separate but attached canal in the foramen. In the orbit it proceeds forward, keeping this lateral relation, for a short distance, when it turns upward, and crosses the upper side of the optic nerve, separating the nerve at that point from the rectus superior, to reach the paries medialis, where it proceeds forward along that wall, to end at the anterior termination of the wall, where it divides into the frontal and dorsal nasal branches.

These branches, after emerging on the outer side of the septum orbitale, anastomose directly into the angular portion of the external maxillary artery. This is known as the Dorsal Nasal Branch, while the frontal branch, going through the supra-trochlear foramen with the supra-trochlear nerve, is distributed to the medial part of the forehead, anastomosing medialwards with the same artery of the other side and lateralward with the supra-orbital.

The opthalmic artery supplies the principal nourishment to all the contents of the orbit, and has numerous branches anastomosing with the anterior maxillary arteries, which supply the face in the adjoining regions of the orbits.

The Arteriae Posteriores Ciliares (the Posterior Ciliary Arteries) are usually six or eight in number, and issue from the opthalmic as it winds around the optic nerve. These sub-divide into about twenty branches before they reach the eyeball, which pierce the sclera forming a circle around the optic nerve. They terminate in the choroid coat where they are known as the Posterior Short Ciliary Arteries. Two of the branches pierce the

sclera, one on each horizontal side of the optic nerve, about 0.5 mm. further removed than the others. These two are known as the Posterior Long Ciliary Arteries, which, piercing the sclera in a very horizontal course, lie between the sclera and the choroid, and proceed, without branching, to form the major circle of the iris at the anterior border of the ciliary body. The ending branches of this circle supply the iris and the ciliary body.

Coincident with, or before giving off, the ciliary branches, and while it lies below the optic nerve, there issues from the opthalmic the Arteria Centralis Retinae (Central Artery of the Retina), which pierces the nerve on its lower side in company with the central vein and a sympathetic branch from the ciliary nerve (Tiedeman's Nerve). These vessels pierce the optic nerve about 10 mm. from the foramen opticum end, and, gaining the central position in the nerve, maintain that position to their terminal distribution in the retina. While in the nerve, this artery gives off anterior branches to the nerve septa and posterior branches which supply the nerve into the optic foramen, both anterior and posterior branches sending lateral branches to supply all the substance of the nerve included within its separate sheaths.

The Arteriae Ciliares Anteriores (Anterior Ciliary Arteries) are quite important, as they pierce the sclera anterior to the recti muscle insertions, and help form the major circle of the iris, where they connect with the posterior long ciliary arteries. The anterior ciliary are branches of the muscular branches of the opthalmic, and are divided in pairs, two to each muscle (occasionally the lateral rectus receiving but one stem); these branches, on reaching the anterior tendon position, divide into a penetrating branch and an episcleral branch, to anastomose with the conjunctival vessels.

The Arteria Lacrimalis (Lacrimal Artery), one of the largest trunks of the opthalmic, branches from the opthalmic lateralwards to the optic nerve, proceeding along the superior edge of the rectus lateralis, gives off branches to the lacrimal gland, and supplies branches to rectus lateralis and the rectus superior. Its terminal branches, after it supplies the gland, are distributed to the conjunctiva and the eyelids, here known as the palpebral branches,

which, running in the two lids medialwards, anastomose with the medial palpebral arteries, forming the superior and inferior arterial circles of the lids. The palpebral branches give off branches to supply the superior lateral aspect of the forehead. Before leaving the orbit, the lacrimal sends two branches through the foramina zygomatico-temporale and zygomatico-faciale, to anastomose with the deep temporal and the tranverse facial arteries, external to the orbit. It also sends a recurrent branch through the lateral angle of the fissura orbitalis superior, to anastomose with the middle meningeal.

The Arteria Supra-Orbitalis (Supra-Orbital Artery) arises from the opthalmic as that artery approaches the rectus medialis on its way to the medial wall. The supra-orbital swings around the medial borders of the rectus superior and the levator palpebrae, to attain a position above the levator, between which and the periorbita it proceeds, accompanying a nerve of the same name, and emerges from the orbit through the supra-orbital notch. It anastomoses with branches of the superficial temporal and the frontal. While passing through the supra-orbital notch it frequently gives off a minute branch, which penetrates at this point the frontal bone, to supply that bone and the adjoining sinuses.

The Arteriae Ethmoidales Anteriores et Posteriores (Anterior and Posterior Ethmoidal Arteries) issue from the opthalmic as it courses along the paries medialis of the orbit; they lie between the obliquus superior and the rectus medialis. The posterior is the smallest, which on emerging through the posterior ethmoidal canal, supplies the posterior ethmoidal cells and the upper posterior lateral wall of the nasal cavity and sends a branch to the dura called the meningeal branch.

The anterior, on emerging through the anterior ethmoidal canal, in company with the anterior ethmoidal nerve, enters the cranium, where crossing the lamina cribrosa to a sagittal position, it descends to the nasal cavity in a groove on the posterior surface of the os nasale, to the top of the nose. It supplies branches to anterior and middle ethmoidal cells, the frontal sinus; the mucous membrane of the nose, and the anterior dura mater.

The Arteriae Mediales Palpebrales arise from the opthalmic

medialwards just as it pierces the septum orbitale, then, separating into an upper and lower branch, these form the medialward end of the palpebral arches, which anastomose with the corresponding branches from the lacrimal artery. The lacrimal sac is supplied by the nasal branch of the ophthalmic, in conjunction with the angular branch of the external maxillary.

The Arteria Infra-Orbitalis (Infra-Orbital Artery) arises from the arteria maxillaris interna, and its course is directly under the periorbita. At the inferior orbital fissure, it enters the infraorbital canal and emerges on the face through the infra-orbital foramen. From its position in the infra-orbital fissure it sends branches to the rectus inferior, obliquus inferior, and the lacrimal gland. On emerging on the face it sends branches to the lower lid, the lacrimal sac, and the medial canthus region, which branches anastomose with the terminal branches of the opthalmic and external maxillary branches of the facial.

The venous circulation of the orbit corresponds generally to the branches of the opthalmic artery, excepting, perhaps, the anastomosis of the naso-frontal veins, which is with the facial.

The branches of the veins of the orbit gradually converge until they form two principal trunks, namely, the Venae Opthalmicae Superior and Inferior, which may leave the orbit separately or as a single vessel, through the annulus Zinn at the apex of the muscular cone, to empty into the Cavernous Sinus.

The Vena Opthalmica Superior (Superior Ophthalmic Vein) begins at the superior medial angle of the orbit, from the naso-frontal branches that accompany the supra and infra-trochlear branches of the medial palpebral arteries and the supra-orbital arteries. It follows the same general course as the ophthalmic artery, receiving the two superior branches of the venae vorticosae and the vena lacrimalis, with the veins from the conjunctiva, and also the central vein of the retina.

The Vena Ophthalmica Inferior (Inferior Ophthalmic) starts at the inferior medial angle of the orbit, and follows along the inferior wall. It receives the venous blood from the lacrimal sac, the lower lid, the conjunctiva, and the two inferior branches of the Venae Verticosae.

This vein anastomoses with the superior ophthalmic posteriorly, and sends a branch through the inferior orbital fissure to join the Pterygoid Venous Plexus, while the main trunk, having entered the muscular cone, leaves the orbit as described above.

There are no valves in any of the ophthalmic veins, which no doubt is of clinical importance, as these veins all empty into the cavernous sinus. There are no lymphatic glands or lymphatic vessels in the orbits.

Orbital Nerves.

The orbital nerves are the Oculo-Motor or Third, the Trochlear or Fourth, the Ophthalmic Division and a small branch of the Maxillary Division of the Tri-Facial or Fifth, the Abducens or Sixth, and Sympathetic Branches from the Internal Carotid Plexus.

As these are all accessory to the proper functioning of the optic nerve, they will be followed throughout with much interest.

The Nervus Oculomotorius, (The Oculo-Motor or Third Nerve) supplies generally the motor impulses to all the muscles of the orbit, excluding the rectus lateralis and the obliquus superior. It supplies motor filaments to the ciliary ganglion, which in turn transmits these motor impulses through the efferent sympathetic motor branches to the ciliary muscle and spincter pupillae.

The oculo-motor has its nucleus of origin in the central gray matter on the floor of the cerebral aqueduct; it is in reality a collection of smaller nuclei, arranged in two rows, opposite each other. The posterior end of each column is in close apposition with the nucleus of the trochlear nerve. These several nuclei are supposed to be individually responsible for the motor impulses to the separate muscles they respectively supply; anteriorly these fibres extend into the gray matter of the floor of the third ventricle.

The oculo-motor nucleus synapses with the occiptal cortex of the cerebrum through the optic radiation, while through its close lateral connection with the medial longitudinal bundle (fasciculus longitudinalis medialis) it is connected with the trochlear, vestibular, abducens nuclei, and the facial. Its connection with the

optic nerve is through the superior quadrigeminal body, by direct synapse from that body.

The Fasiculus Longitudinalis Medialis contains ascending and descending fibers assembled in a compact column, whose specific office is to co-ordinate the reflex motor response to and from all the cranial and spinal stimulations and particularly those that affect the conjugate movements of the eyes.

Also it shows on its dorso-lateral surface a connection with the Edinger-Westphal group from the sympathetic (Splanchnic) Efferent Nuclei, which accompany its nerve fibers into the ciliary ganglion and there synapse.

The axones of the oculo-motor nerve, or, as it should be regarded, the collection of nerve fibers from the various nuclear origins, curve around the tegumentum to connect with the medial longitudinal bundle on one side, and the red nucleus and the substantia nigra opposite, and emerge at the inferior side of the oculo-motor sulcus medialward to the Pedunculus Cerebri, in front of the Pons.

This nerve proceeds forward between the posterior cerebral and the superior cerebral arteries, where, lateral to the posterior clinoid process, it emerges from the dura to enter the cavernous sinus. Here, as it enters the fissura orbitalis superior, it splits into two branches, which enter the orbit through the annulus Zinn at the apex of the muscular funnel. From its origin to its orbital entrance, it is about 57 mm. long, of which 20 mm. lies along the floor of the third verticle. Its nuclei of origin occupy a longitudinal space of about 5 mm. While crossing the cavernous sinus this nerve receives sympathetic branches from the carotid plexus, and also a small sensory branch from the fifth, or trifacial.

After its division, and having reached the orbit, the smaller superior branch proceeds upward, on the lateral side of the optic nerve, to supply the rectus superior and the levator palpebrae superior. The other branch divides into three stems, which supply the rectus medialis, the rectus inferior, and the obliquus inferior. From this latter stem is given off one or two short motor roots to the ciliary ganglion.

The entrance of the motor roots of the recti muscles are all on the orbital side of the bellies of these muscles.

Mendel believed that fibres from the oculo-motor nucleus, in the medial longitudinal bundle, connect with the fibers of the facial nerve, and thereby supply the orbicularis oculi and the corrugator superciliaris, bringing these muscles under the same control of the same nucleus as the levator palpebralis superior. This view is tenable on account of these upper group of muscles being spared in cases of facial paralysis.

The fact that this nerve carries sensory fibres as well as motor fibers may be clearly demonstrated, for, after the instillation of cocaine in the eye, the muscles will respond promptly as usual.

On paralysis of this nerve, there is noticed pupillary dilation from paralysis of the sphincter, loss of accommodation from paralysis of the ciliary muscle, and marked diplopia, with ptosis.

The Nervus Trochlearis (Trochlear or Fourth Nerve) supplies only the obliquus superior. Its nucleus of origin is a small mass of gray matter at the lower end of the column of nuclei of the oculo-motor, lateral to the medial longitudinal bundle. From its origin it curves backward until the fibres passing through the lateral gray matter, reach the medial side of the trigeminal root, which it follows to the lower edge of the inferior colliculus. Here they make another bend, dorsally, and enter the anterior medullary velum, where the nerve makes a complete decussation with its fellow of the opposite side, now emerging from the roof of the brain inferior to the brachium conjunctivum. This is the only motor nerve that emerges dorsally.

This nerve is extremely thin, and from its origin to its distribution measures over 80 mm. in length, half of which is within the cranium.

After emerging from the roof of the brain behind the optic tract, it proceeds forward at the base of the skull, between the oculo-motor and the trifacial, where it enters the superior angular end of the superior orbital fissure, above the annulus Zinn, then crossing over the bellies of the rectus superior and the levator palpebrae superior, separating those muscles from the paries superior, it enters the belly of the obliquus superior. This nerve,

like all the other nerves crossing the cavernous sinus, receives a sympathetic branch from the carotid plexus and a slender sensory filament from the trifacial.

This nerve is rarely affected alone, but usually in conjunction with the oculo-motor.

The Nervus Trigeminus (Trifacial or Fifth), is the largest cranial nerve and is the principal sensory nerve of the face and orbit, while it supplies motor impulses to the muscles of mastication. In its origin it is similar to the spinal nerves, having an afferent sensory root with its own sensory ganglion (this is the larger root), and an efferent motor root, which arises from a motor root nucleus within the medulla. This nerve presents more extensive connections than any other cerebral nerve.

While we are particularly interested in the ophthalmic division of this nerve, which is the smallest of the three divisions, yet the origin of the whole nerve must be understood. Again, the motor root is so much the smaller, that the sensory activity of the fifth is the usual function ascribed to it.

The fibers of the sensory root arise outside the brain and are formed from the fibers of the semilunar ganglion. This ganglion lies in a cavity near the apex of the petrous portion of the temporal bone. These fibers pass posteriorly and enter the pons, there dividing into superior and inferior roots; the superior ending is somewhat rounded and is situated lateralward to the motor nucleus. The lower root is the long pointed end which is directly continuous with the Substantia Gelatinosa of the spinal medulla, (Spinal Fifth.) This latter root is spoken of as the spinal root. This sensory nucleus lies on the middle of the lateral side of the pons, directly below the brachium conjunctivum, and is continuous with the spinal root. The roots of the trigeminal, on reaching this sensory fifth nucleus, send ascending branches to synapse within this nucleus, while the descending branches form the spinal root. This root disappears about the level of the second cervical vertebra.

The motor nucleus lies in the upper part of the pons, lateralwards and posterior to the floor of the fourth ventricle, having the same relative position with the motor nuclei of the facial,

vagus and glosso-pharyngeal. It is bordered lateralward by the sensory nucleus of its own nerve.

The mesencephalic root lies just above these two, and as to whether these fibers are sensory or motor is a moot question.

On leaving the pons as a large sensory and a small motor root, these branches proceed to the superior angle of the petrous portion of the temporal bone where the nerve lies in the cavity, called Cavum Meckelii; they unite with the ganglion semiluminare, the motor root, however, passing below and not entering the ganglion. This ganglion receives sympathetic filaments from the carotid plexus. From its convex lateralward border its gives off three branches, the ophthalmic, the maxillary, and the mandibular. This latter branch is the only one with which the motor root is incorporated. All of these branches, however, unite with the facial at their peripheral endings.

The Nervus Ophthalmicus (Ophthalmic or First Division of the Fifth), proceeds forward to the orbit through the fissura supra-orbitalis, and while traversing the cavenous sinus, gives off sensory fibers to the third, fourth, and sixth nerves, also it gives off a recurrent branch to supply the tentorium cerebelli. At its point of entrance, though the superior orbital fissure, into the orbit, this flattened nerve divides into three branches, which enter the orbit separately, called the Lacrimal, Frontal, and Naso-Ciliary.

The Nervus Lacrimalis, (Lacrimal Nerve), enters the orbit through the lateral angle of the fissura orbitalis superior, outside and above the annulus Zinn, where, enclosed in its own sheath of periorbita accompanied by the lacrimal artery, it reaches its place of distribution. It lies in its course along the superior border of the rectus lateralis, and supplies the lacrimal gland, near which it receives a filament from the zygomatic branch of the maxillary nerve. After supplying the stroma of the lacrimal gland, it supplies the conjunctiva and the skin lateralwards of the lids.

The Nervus Frontalis, (Frontal Nerve), enters the orbital cavity through the fissura orbitalis superior, also outside the annulus Zinn, proceeds along the paries superior above the levator

palpebrae superior muscle, and there divides into two branches, the Supra-Orbital and the Supra-Trochlear.

The frontal is the largest branch of the ophthalmic, while the supra-orbital is the largest division of the frontal.

The Nervus Supra-Orbitalis (Supra-Orbital Branch) proceeds directly forward through the supra-orbital groove or foramen, to the forehead, which it supplies, giving small branches to the upper lid and into the frontal sinus. Like all of these nerves, connects peripherally with branches of the facial.

The Nervus Supra-Trochlearis (Supra-Trochlear Nerve) proceeds obliquely medialward and forward above the tendon of the obliquus superior, to reach the medial wall of the orbit. It leaves the orbit through an opening between the septum orbitale and the margo orbitae, giving off branches to the conjunctiva and skin of the upper lid medially, and supplying the forehead on its medial aspect. Before leaving the orbit it sends a branch to the infra-trochlear branch of the naso-ciliary. The external muscles of the forehead, therefore, are supplied with sensory branches of the fifth nerve.

The Nervus Naso-Ciliaris (Naso Ciliary Nerve) enters the orbit through the superior orbital fissure, continuing through the annulus Zinn, between the two branches of the oculo-motor nerve. It lies on the lateral side of the optic nerve at its entrance, then it crosses over the optic nerve beneath the rectus superior, proceeding towards the medial wall, to leave the orbit through the anterior ethmoidal foramen. After passing through this foramen, this nerve is named the Anterior Ethmoidal. It now enters the cranial cavity, to be finally distributed to the medial and lateral walls of the nose, finally to emerge on the dorsum nasi to supply the integument of the lower part of the nose, here called the External Nasal Nerve.

Before crossing the optic nerve it gives off a filament about 8 mm. long to the ciliary ganglion (Radix Longa Ganglii Ciliaris), after which it gives off two long ciliary branches. Just before entering the anterior ethmoidal foramen it gives off a slender branch, which proceeds forward close to the bone, called the Infra-Trochlear Nerve (Nervus Infra-Trochlearis), which is quite important,

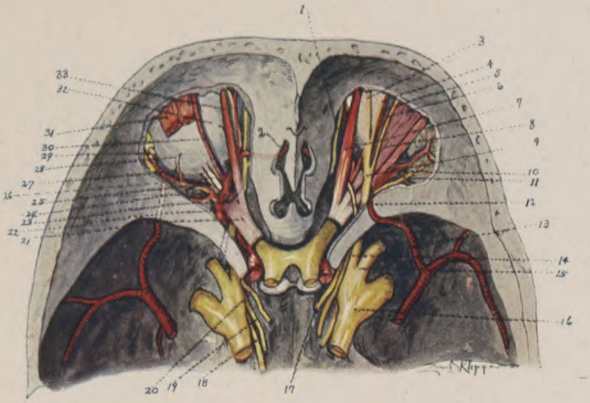
as it supplies the tissues and membranes around the medial canthus, the sac, the canaliculi, and the root of the nose.

The long ciliary nerves, after joining some of the short ciliary nerves, which contain sympathetic fibres, pierce the sclera with their accompanying long ciliary arteries, and finally reach their position of distribution.

There are four small ganglia connected with the three trunks of the fifth nerve—the Ciliary, Spheno-Palatine, Otic, and the Sub-Maxillary. These are all connected with the sensory fibers of the fifth, but they are in reality terminal ganglia of the sympathetic system, in which are combined motor, sensory, and secretory fibers, all of which are branches of the adjoining cerebral nerves. The distribution of the efferent fibers from these ganglia contain a combination of *all* the impulses of the entering roots. The arborizations of the ending cells synapse closely with the ganglion cells. These endings are similar to the endings found in the central neuron of the retina.

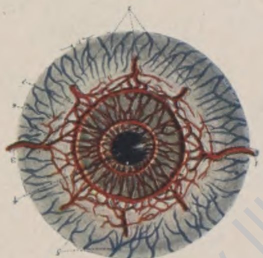
The ciliary ganglion is a small reddish ganglion about 2 mm. long, 1 mm. wide, and not quite 1 mm. thick. It lies about 8 mm. in front of the annulus Zinn on the lateral aspect of the optic nerve imbedded in the orbital fat. Its roots are three, namely, Sensory or long root, which arises from the naso-ciliary branch of the ophthalmic nerve; Sympathetic, which arises from the cavernous plexus on the internal carotid artery; and the Motor, or short root, which arises from the inferior division of the oculo-motor nerve. The last named may be known as the Para-sympathetic, as it contains fibres which synapse in the ganglion; these fibres come from the anterior nuclei of the third nerve; when they reach this ganglion, they are continued by efferent fibers to the distribution of the short ciliary nerves. These short ciliaries supply contractile impulses to the sphincter and constrictor pupillae muscle fibers, while other fibers are the accommodation fibers supplying the contractile impulses to the ciliary muscle. These have a similar origin and course, but do not synapse in the ciliary ganglion.

The Nervi Ciliares Breves, (Short Ciliary Nerves), proceed from the anterior angles of the ganglion in about 8 branches. These travel forward, dividing into about twenty branches, and



Orbits From Above

(1) Naso-ciliary nerve. (2) Ethmoidal branch naso-ciliary artery. (3) Supra-trochlear branch. (4) Frontal branch. (5) Frontal artery and veins. (6) Supra orbital branch. (7) Superior oblique muscle. (8) Levator palpebra muscle. (9) Frontal nerve. (10) Lacrimal artery and vein. (11) Lacrimal nerves. (12) Trochlear or 4th nerve. (13) Meningeal branch of Lacrimal artery. (14) Ophthalmic division of trifacial. (15) Maxillary branch of trifacial. (16) Gasserian ganglion. (17) Internal carotid artery (18) Abducens nerve. (19) Trochlear nerve. (20) Oculo-motor nerve. (21) Annulus of Zinn. (22) Ophthalmic artery. (23) Naso-ciliary nerve. (24) Lacrimal artery. (25) Long ciliary arteries. (26) Optic nerve. (27) Muscular branch of lacrimal artery. (28) Vena vorticosa. (29) Lacrimal gland. (30) Supra-orbital artery and vein. (31) Levator palpebrae and superior recti muscles. (32) Bulbus oculi. (33) Superior oblique muscle.



Circulation of Iris

Long ciliary artery. (2) Short ciliary arteries and anterior ciliary arteries. (3) Long ciliary artery. (4) Pupil. (5) Veins. (6) Arteria circulus minor (Minor arterial circle.) (7) Arteria circulus major. (Major arterial circle.) All the illustrated arterial branches are accompanied by veins except one (1) and three (3) whose outgoing circulation, with that of the short ciliary arteries, is taken up by the veins of the venae vorticosae.

arrange themselves around the entrance of the optic nerve, to enter the emissarias with the short ciliary arteries. The various functions of these nerves have been discussed.

The Nervus Maxillaris (Superior Maxillary Nerve) is the second division of the trifacial and is purely sensory. It is the second in size of the three branches, and originates from the middle of the semilunar ganglion. When leaving the skull through the foramen rotundum, it bends around inwardly, to attain a position below the middle floor of the orbit, and runs along the inferior orbital fissure, through the infra-orbital canal, out through the infra-orbital foramen, to be distributed to the skin of the face and lower eyelid. It sends branches to the side of the nose, the upper lip, and the temples, while previous to its emergence on the face it supplies the teeth of the upper jaw, the posterior ethmoidal cells, maxillary sinus, mucous membrane of the nose and upper pharynx, including the back half of the roof of the mouth. A branch near its origin is given off to the middle meningeal region of the dura. In the inferior orbital fissure a malar branch is directed into the orbit, which divides along the lateral wall into the temporal and the facial branches. The temporal branch, ranging upward on the lateral wall of the orbit, reaches the temporal canal of the malar bone, through which it leaves the orbit and enters the temporal fossa. Before leaving the orbit it receives a filament from the lacrimal branch of the ophthalmic division of the trifacial. After emerging in the temporal fossa, where it perforates the temporal and orbicularis oculi, it is distributed to the skin of the cheek, and connects with motor branches of the facial. The facial branch reaches the cheek through the malar canal of the zygomatic bone, where its end-filaments connect with the facial nerve.

The dental branches of this nerve are given off at the entrance of the inferior orbital fissure, when this nerve first reaches that fissure.

The facial branch supplies the skin and conjunctiva of the lower lid, the skin on the side of the nose and the upper lip, including its mucous membrane. These branches to the upper lip are joined to many branches of the facial, and become known as

the Infra-Orbital Plexus. Before giving off the dental branches, this nerve gives off one to three fibers to the spheno-maxillary ganglion, which is situated near and below the spheno-palatine foramen, the efferent fibers of which supply the nasal cavity and upper pharynx and palate. Also it sends a fiber to supply the orbitalis muscle of Müller which covers the orbital side of the inferior orbital fissure; this muscle is recognized as an involuntary muscle. The endings of this portion are continued to the posterior ethmoidal cells, where they terminate.

The Sixth Nerve (Abducens), is the nerve of the external rectus. It originates in a small mass of gray matter in the floor of the fourth ventricle, very close to the origin of the fifth. In its course forward, from the lower border of the pons it lies just above the pyramid of the medulla oblongata, and enters the cavernous sinus on the outer side of the internal carotid artery. After leaving the sinus, it enters the orbit through the superior orbital foramen, within the ligament of Zinn, medial to the rectus lateralis, which muscle it finally enters on its medial side near the middle of its belly.

Fractures of the base of the skull are often first noted by the paralysis of this nerve involving it on account of its deep, long course in the base of the skull.

While tranversing the cavernous sinus, this nerve receives filaments from the sympathetic of the carotid plexus and also a small filament from the ophthalmic division of the fifth nerve.

The Seventh or Facial Nerve is a mixed nerve, the roots of which are of a large motor and a smaller sensory type, the motor impulses being the efferent force.

We mention this nerve, because of its distribution around the orbit, and its connection on the face with the branches of the fifth.

The origin of the seventh is near the sixth, on the floor of the fourth ventricle. It emerges from the lower border of the pons, below the fifth, passes through internal acoustic foramen, through the facial canal of the petrous portion of the temporal bone, reaches the parotid gland, to be distributed to the muscles of the face, and the upper and lower lids, where it combines freely

with the endings of the three divisions of the fifth nerve, which it meets at these points.

Nerves.

The number of fibers in the sixth nerve are estimated by Macalister as 2,000, by Rosenthal 2,000 to 2,500, by Tergast as 3,600. All agree that they are mostly large, with some medium sized, while the muscle it supplies (the external rectus) contains about 5,000 muscle fibers.

The fourth nerve contains about 1,200 fibers, (Gaskell), while Macalister claims 2,000. The two authors say coarse fibers, while the first adds that one-fourth are small fibers. It is distributed to the superior oblique, which contains about 2,000 muscle fibers.

The third nerve contains about 15,000 fibers (Quain, Macalister) which are generally large, with some small ones intermingled. The five muscles it supplies in the orbit contain about 40,000 muscle fibers.

The relatively large size and short coupled position of the motor nerves of the extrinsic muscles have excited quite a voluminous discussion from our physiologists for a long time, yet we apparently know but little about the two opposing muscular forces that are ever present in ocular movements, that is, the traction and the steadying restraint.

CHAPTER XII.

The Optic Tract and Vision.

The optic tract begins at the chiasma proper; however, there is a portion of the optic nerve, leading from the orbital entrance of the foramen opticum to the chiasma, which, while it is intra-cranial in fact, is extra cranial in its physical relations. The length of the optic foramen is fashioned by the flat sides of the two roots of the small wings of the sphenoid. The inferior canal length along the width of the inferior root is about 10 mm. while the superior canal length along the width of the superior root is about 5 mm. Most of this difference in length is intra-cranial. The orbital orifice of the foramen opticum is nearly always on the same plane, so that the measurement of the interosseous portion of the optic nerve, like the intra-orbital portion, varies according to the side from which the measurement is taken; however, the length of the intra-cranial portion, taken from the orbital orifice to the chiasma, is about 17.5 mm. in length. In the canal the optic nerve is held by its sheath of dura, which not only forms a close sheath around the nerve and the accompanying artery, but constitutes the periosteum of the bone itself. In the canal the nerve is somewhat rounded, while on its exit into the cranium it becomes somewhat flattened. Having lost two of its sheaths at the orbital opening of the optic canal, viz., Tenon's and the dural sheath (the latter becoming incorporated in the periosteum), the optic nerve becomes smaller. The intra osseus portion measures in transverse diameter about 3.5 mm., while intra-cranially, it measures 5 mm. wide by 2.5 mm. thick.

The Optic Chiasm (Chiasma Optica) is the commissure where the two optic nerves meet, forming an oblong body behind the optic groove of the sphenoid bone, its average measurements are 13 mm. long, 8 mm. wide, and 4 mm. thick. It forms quite a prominence on the floor of the third ventricle, while the internal carotids are close to its lateral sides. From the lateral posterior angles of the chiasma, the so-called optic tracts (Tractus Opticus) sweep back, each diverging around to the back of the Thalamus between the Hippocampal Gyrus and the Pedunculus Cerebri,

terminating in the mid-brain on their respective sides in three branches, which are distributed to the pulvinar of the Thalamus, Lateral Geniculate Body, and the Superior Quadrigeminal Body (Superior Colliculus), entering the latter by way of its arm, or Brachium. This division point is known as the Lower Visual Center.

On the posterior medial margin of the optic tract is seen a distinct band of fibers, to all appearance resembling the fibers of the tract, which connect the Medial Geniculate Bodies. These fibers have nothing to do with vision: the band is called the commissure of Gudden, after the man who first demonstrated it as a separate entity, and it is solely related to hearing.

The fibers of the optic tract originate from the lateral half of the retina of their own respective sides, the medial half of the retina of the opposite side, and a part of the fibers of the macula region of both sides. These latter fibers, having attained the central position in the optic nerve, decussate equally to each side. There are also a certain number of efferent fibers, noted by their exceeding fineness, which travel from their origin in the brain back to the retina; these decussate the same as the others, but the involved impulses are directed in an opposite direction.

These retinal fibers when reaching the chiasma decussate as described, and synapse in various manners, viz., the fibers going to the superior quadrigeminal body reach it through the superior brachium, and forming a superficial layer of white fibers, then sink into its substance, to synapse by arborazations around its nerve cells.

The fibers (and this refers to about four-fifths of all the fibers of the tract) proceed to the lateral geniculate body, where some attain the center and some spread out into lamellae to synapse with the gray matter of this body. Both the superficial and the deep fibers that enter this body stay there; however, a certain number of each proceed onward to enter and synapse in the Pulvinar of the Thalamus (Pulvinar means cushion), or posterior cushion of the Thalamus.

From this place of the primary optic ganglia, new axones arise which carry the visual excitation to the region of conscious-

ness and memory. These axones leave the lateral posterior aspect of the Thalamus and curving around the Cornu Posterius of the Ventriculus Lateralis—there radiate through the optic Radiation of Gratiolet, ending chiefly at the Cuneus and the parts adjacent to the Calcarine Fissure—an area which, if spread out, would cover about 3,000 sq. mm. situated at the posterior inferior section of the Occipital Lobe.

The fibers of the first division of the optic tract are divided into centrifugal and centripetal fibers, to denote the direction taken by the impulses aroused through divergent stimulations; however, this will always be a matter of conjecture. There is a demonstrated direct connection between the tract by the axones of cells from the anterior quadrigeminal body which unite with the posterior longitudinal bundle; this controlling the conjugate movements of the eye; which bundle is in contact with the oculo-motor nuclei, which in turn, through the central gray matter, unites with all the sensory and motor nuclei of the orbit and eyeball, notably with the third, fourth and sixth nerves.

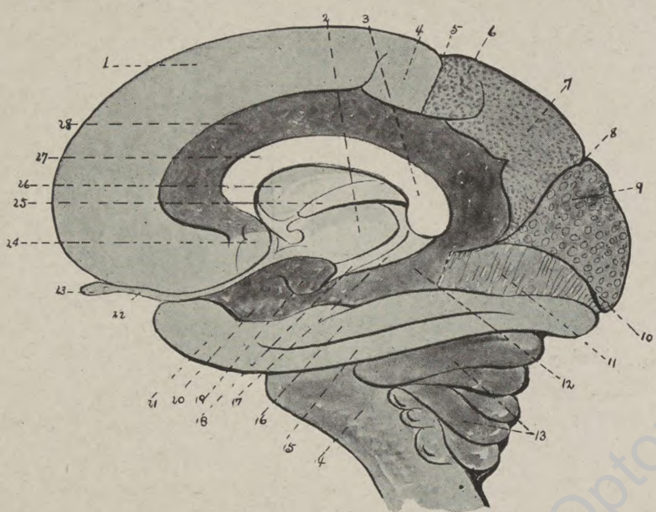
The optic tract, through one of its primary ganglia, the thalamus, is connected through the inner Lemniscus to the Medulla Oblongata and the Spinal Cord.

The Third Ventricle is the narrow cleft remaining of the undivided portion of the primary invagination of the primary vesicle, at the root of the tranverse invagination of the optic vesicle, in which anterior floor the peduncles of the optic nerve are connected by a tranverse bundle of fibers. This is the connection within the base of the third ventricle that connects the primary optic ganglia together, and underneath this anterior lateral wall of the third ventricle, in connection with the central gray matter, lie the optic thalami.

The Thalami are two large oval masses of gray matter, developed from the lateral walls of the interbrain. At the posterior and medial part of this mass is a large and rounded projection, the Pulvinar, and between the pulvinar and the beginning of the peduncle of the Pineal Gland, is found the Area Trigonum Habenulae and the club-shaped Ganglion Habenulae.

The internal surface of each thalamus is flat and constitutes

the outer boundary of the third ventricle. The posterior extremity is composed almost entirely of the prominence called the pulvinar, which latter is composed principally of gray matter and is connected with the optic tract and the occipital lobe. On the posterior and inferior surfaces of the pulvinar exist two elevations of gray matter, the Internal and External Geniculate Bodies. The



SIDE VIEW OF SAGITAL CUT BRAIN.

(1) Gyrus frontalis superior. (2) Thalamus. (3) Hippocampus. (4) Gyrus centralis anterior. (5) Sulcus centralis (fissure of ucolando). (6) Gyrus centralis posterior. (7) Precuneus. (8) Sulcus parieto occipito. (9) Cuneus. (10) Sulcus calcarineus. (11) Gyrus linguinalis. (12) Fascia dentata. (13) Cerebellum. (14) Medulla oblongata. (15) Gyrus temporal inferior. (16) Gyrus fussiformis. (17) Crus fonicis. (18) Fimbria. (19) Auditory receptive center (uncus). (20) Piriform area. (21) Gyrus hippocampus. (22) Olfactory tract. (23) Olfactory bulb. (24) Olfactory center. (25) Corpus fornicis. (26) Septum pellucidum (27) Corpus callossum. (28) Gyrus cinguli.

internal geniculate body is covered with a layer of white fibers and is connected on each side with the auditory tract. The external or outer geniculate body is of a yellow gray color, because composed chiefly of gray matter, and receives fibers from the optic tract.

Both of the geniculate bodies are connected with the corpora

quadrigemina, the internal being connected with the posterior or inferior corpus quadrigeminum, and the external with the anterior or superior corpus quadrigeminum.

The optic thalami have a double connection with all parts of the cerebral cortex, first by bundles of fibers from the different nuclei of the thalami, called the projection fibers of those bodies, and secondly by axones from the pyramidal cells of all parts of the cortex. In a general way the thalami are anatomically related with the cerebrum through their anterior portions to the frontal lobes, the parietal sides with the parietal lobes, the ventral ganglion with the operculum; the posterior ganglion corpus geniculatum externum and pulvinar with the Gyri of the Occupital lobe, the corpus geniculatum internum and posterior ganglion with the temporal lobe. This jutting-out system of fibers emerge through the internal capsule in bundles, which have been termed Laminae Medullaris, or Peduncles of the Optic Thalamus. They divide each thalamus into the anterior, medial and outside, viz., the Ventral, the Posterior and the Pulvinar.

Recapitulation.

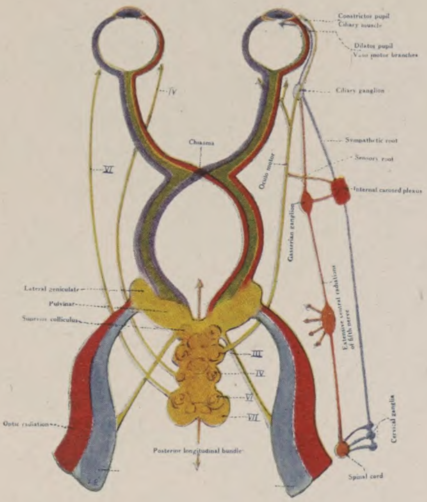
The Optic thalamus has an intricate connection with all portions of the cerebral cortex, by axones from the cells of the various composing nuclei, and by axones from the pyramidal cells of all sections of the cerebral cortex.

It is connected by axones to first division of the Optic Tract, which synapse about the cells of the pulvinar and external geniculate body.

It connects with the occipital lobe by axones from the cells of the pulvinar, which synapse with the pyramidal cells of the cortex of the occipital lobe, and by axones of that lobe which synapse with the cells of the pulvinar.

The anterior nucleus of each thalamus connects with the corpus albicans, which synapses the fornix fibers with the hippocampal and uncinate gyri.

The cells of the ganglion habenulae originate fibers which form the "Fasciculus Retroflexus of Meynert," and synapse with the interpeduncular Ganglion.



Schematic Drawing

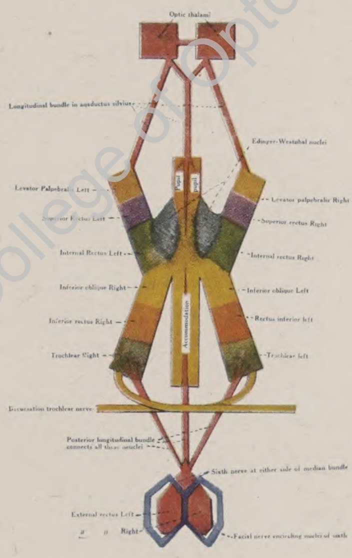
Illustrating the pupillary and accommodation reflex-association through the ciliary ganglion.

The constrictor pupillae and the ciliary muscle, acting together in near vision, produce the function of accommodation, which is accompanied by convergence, all influenced by the ciliary ganglion, while the dilator and vaso motor branches are influenced by the sympathetic branches of the superior cervical and do not synapse in the ciliary ganglion.

Light reflexes cause a pupillary reflex through the ciliary ganglion, by the influence of the fibers from the Edinger-Westfeld n u c l e u s, sending visceral efferent impulses through the oculo-motor fibers.

Schematic Drawing of the Nuclei of Origin of the Motor Nerves of the Eyes

Showing their intimate connection with the optic thalami and the longitudinal bundle, also the close position to the reflex centers of the pupils and accommodation with the Edinger-Westfeld group of efferent visceral nuclei are interposed; the several groups are shown in colors, yet the synapsis are directly from one group laterally to each other, and all of them synapse in the longitudinal bundle with all the rest.



The fibers of the median fillet or lemniscus send fibers, by way the posterior capsule, into the parietal lobe forming the cortical fillet or lemniscus.

The thalamus synapses with fibers which originate from the cells of the Neucleus ruber, and fibers from the superior cerebellar peduncles; this connects the thalamus with the opposite cerebellar hemisphere.

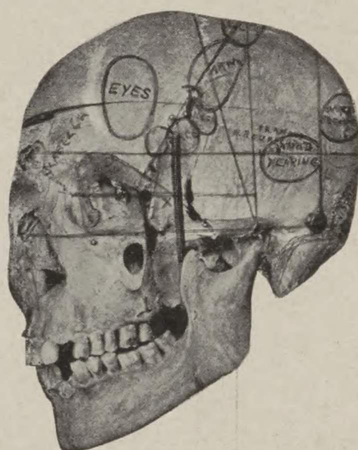
Vision.

Physiologists are unanimous in their opinion, that the first stage of the higher visual centers is located in the cortex of the occipital lobes around the Calcarine Fissure, in the wedge shaped space between the Calcarine Fissure, and the Parieto-Occipital Sulcus. The exact extent of this space from clinical experiment is not definitely determined, but that this is the approximate area is a recognized fact. This space is characterized by a white line in the gray matter, known as the Area Striata (Stria of Gennari) along the lower lip of the Calcarine Fissure, which is held to be the visual sensory area because the destruction of that space causes total blindness. Like all other cortical areas in the brain, these areas are inter-dependent on the other neuron associations of the brain for complete vision. Many investigators have destroyed certain convolutions of the brain without a complete loss of vision, but from the collected cases of fractures and neoplasms in this part of the brain, it is undoubtedly established that this occipital region is the central source of vision.

The cases of lesions in that part of the middle surface of the occipital lobe and all around the calcarine fissure, are always concomitant with a paralysis of the field of vision, which shows always opposite the lesion, either partial or complete, known as Bilateral Homonymous Hemianopsia; this lesion also may be transitory or permanent. One in which the patient has visual hallucinations periodic in character, like a sudden flash of light, with blindness, in the opposite fields; when the total destruction is uni-lateral we have Bilateral Homonymous Hemianopsia, and when on both sides we have total blindness, so that in any of these aforesaid symptoms we must look to the optic tract.

Another point that is of importance is the fact that this area not only receives the impressions, but the memory of sight is located here, as destruction of this superficial area may not cause blindness but the impression of sight will not be recognized as such, and definite responses to sight will not occur.

The areas around the occipital lobe have been divided up into color, location, size., etc., but these locations are not definitely proven (Posey & Spiller).



TOPOGRAPHICAL MAP OF AREAS OF BRAIN.

Indicated on outer side of skull, especially as relates to the visual centers. Line marked X is in the central position of what I think is a relational position, and always indicates the probable depth of the orbit, when this is established I believe it will determine a definite value to myopia and hypermetropia.

The external occipital protuberance marks the lower boundary of the visual center of the brain.

Repeating some of the facts I have previously cited, each optic nerve has, according to Sulzer, about one-half million fibers. The fibers of the optic tract which arise from the cells on the temporal half of the retina do not decussate in the optic chiasma, but are direct fibers and pass backward to their corresponding sides. The fibers from the nasal half of each retina, which are in greater

number than the temporal fibers, cross over in the chiasma and proceed with the fibers of the temporal side.

Only in animals with an overlapping of the fields of vision do we find that there is an incomplete decussation in the chiasma.

Then the fibers from the fovea centralis, which in number are about one-half of the combined other two, and come from the place of the most distinct vision and are the more important, attain the central position in the nerve to the chiasma, where they undergo a partial decussation, and half go to the opposite side. These fibers all continue backward and terminate about the cells of the external geniculate body, the pulvinar of the optic thalamus, and the anterior corpus quadrigeminum. In the tract the fibers are not clearly separated, but each tract contains all the fibers from the corresponding sides of each retina; also there are fibers from the inner geniculate body of one side that follow along the optic tract to the inferior colliculus of the opposite side. This is called the commissure of Gudden, having nothing to do with sight, but is part of auditory system. Inside this is another smaller commissure that of Meynert, also not connected with sight.

From the cells of these primary optic centers new fibers start through the further end of the posterior part of the internal capsule, and thence pass backward through the centrum semiovale to end about the gray cells of the cuneus and lingual gyrus of the occipital lobe. Traveling with the fibers of the optic nerve, it has been almost demonstrated that we may have motor fibers from the iris, but more probable these are fibers mediating the reflexes happening through the sympathetic collaterals. No doubt, through the so-called optic radiation, there are direct fibers through the cortical substance of the brain, which connect the different higher visual centers together, the same as the lower visual centers, and all of these are connected to the sympathetic, motor, and sensory nerve-nuclei-origins.

The origin of the third or oculo-motor nerve, the distribution of which has been referred to, is from a nucleus in the gray substance of the floor of the cerebral aqueduct, somewhat lower than the colliculus superior is in the floor of the third ventricle; it is about 5 m. long. The cells of this nucleus are collected in dif-

ferent sized cell groups, which groups are supposed to have definite fields of action over which they preside; there is so much diversity of opinion that this, like the color centers, will have to be left for more accurate study, but that these two nuclei have decussating and interchanging fibers is proven by the fact that we have conjugate movement of the eyeballs, also that these nuclei are connected with the fourth, fifth and sixth nerve, through this interchange raphe or posterior longitudinal bundle, Fasciculus Longitudinalis Medialis, which connects all these nuclei together, and, through the optic radiation of the superior colliculus, is connected with the higher optic centers.

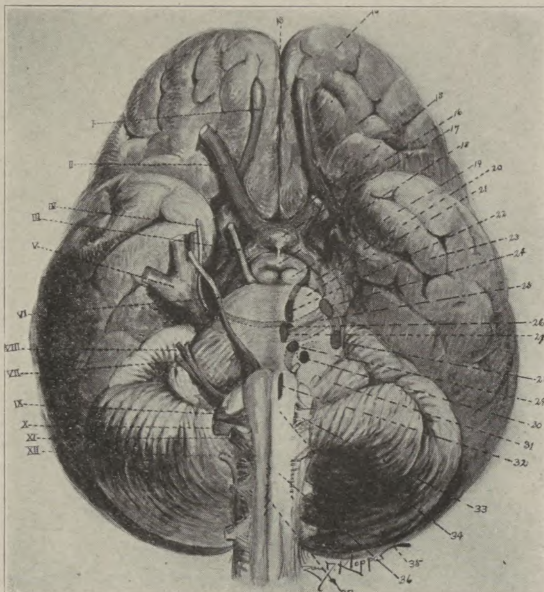
The fourth or trochlear nucleus arises in the floor of the third ventricle, and while separated, seems to be of the same column of cells as the third nerve, which it follows in all its relations to the other parts of the brain.

The sixth or abducens nucleus is a small rounded gray mass directly under the floor of the fourth ventricle. It lies within the loop formed by the facial nerve, but does not communicate with that nerve. The fibers of this nerve do not decussate, but travel the whole width of the pons to reach the cavernous sinus. The central connection, however, is through the posterior longitudinal bundle, (Fasciculus Longitudinalis Medialis), and through its connection with this nucleus superior olivaris it connects the path for eye movements with the auditory apparatus of the Cochlear Nerve, one of whose chief functions is to control equilibration and static sense.

The cortex of the Gyri Angularis is supposed to govern the direct vision of the opposite eye and is the seat of comprehension as governing the visual impressions, while the middle frontal convolution is the center for governing motor impulses.

These two areas are selected from clinical experience more than from our ability to trace anatomical fibers synapsing in these places. The field for the positive location of visual impressions is yet open to investigators, as little has actually been accomplished in that direction.

One of the so-called anatomical explanations may be made as regards the harmonious movements; fibers from the abducens



BASE OF BRAIN WITH NUCLEI OF ORIGIN OF PRINCIPAL NERVES OF EYE INDICATED AS THEY LIE UNDER THE PONS, WERE THE PONS TRANSPARENT.

(I) Olfactory nerve tract showing bulb (Tractus olfactorius). (II) Optic nerve (Nervus opticus). (III) Occulo motor nerve (n. occulo motorius). (IV) Trochlear nerve (n. trochlearis). (V) Tri facial nerve and gasserian ganglion (n. trigerminus and ganglion semilinare). (VI) Abducens nerve (n. abducens). (VII) Facial nerve (n. facialis). (VIII) Auditory nerve (n. acusticus). (IX) Vagus nerve (n. vagus). (IX) Glosso pharyngeal nerve (n. Glosso-pharyngeus). (XI) Accessory nerve (nervus accessorius). (XII) Hypoglossal nerve (n. hypoglossus). (13) Longitudinal cerebral fissure (fissura longitudinalis cerebri). (14) Anterior pole (Polus frontalis). (15) Chiasma (Chiasma opticum). (16) Triple olfactory root (trigonum olfactorium). (17) Hypophysis. (18) Tuber cinereum. (19) Corpus mamillar. (20) Cerebral peduncle (Pedunculus cerebri). (21) Pons (Varoli). (22) Oculo motor nucleus (nucleus n. oculomotorii). (23) Temporal lobe brain (Lobus temporalis cerebri). (24) Corpora quodrigemina (Colliculus superior). (25) Major portion of trifacial nerve (Portio major n. trigemini). (26) Nucleus trochlear nerve (Nucleus n. trochlearis). (27) Principal motor nucleus of trifacial nerve (Nucleus motorius princeps n. trigemini). (28) Lateral geniculate body (Corpus geniculatum laterale). (29) Aducens nucleus (Nucleus n. abducentis). (30) Facial nucleus (Nucleus n. facialis). (31) Flocculus. (32) Motor nucleus region of glossopharyngeal, vagus, and hypoglossal nerves. Just near the nuclear region of the spinal origin of the trifacial nerve. (33) Position of olive of medulla oblongata (Oliva). (35) Pyramid of medulla (Pyramis medullae oblongatae). (36) Anterior column of cord (Medulla spinalis funiculus anterior). (37) Decussations of the pyramids (deccussito pyramidum).

nucleus ascend in the medial longitudinal bundle into the Mesencephalon, and establish connections with that part of the oculomotor nucleus, from which the nerve of the opposite side derives its fibers. If this view is correct, it affords a ready and simple anatomical explanation of the harmonious action of the lateral and medial recti muscle in producing movements of the two eyeballs, simultaneously, to the right and to the left.

CHAPTER XIII.

Embryology and Development.

The primary result of the stimulation that is received by the ovum is a development of the nervous system. This development at first is external; then, as the organism becomes more important, the principal component seeks a position of greater protection internally, leaving externally a series of sense receptors capable of receiving the impressions aroused by their contact with the external influences.

The development and efficiency of these sense receptors or organs are little changed in the whole vertebrata. The eyes of fishes are almost as perfect and quite as complex as the eyes of mammalians.

The elemental type of a sense organ, as displayed in the entire animal division of nature, is an epithelial cell in connection through its nerve extension to a sensory functional center.

Considering this as a beginning, there are two routes by which an increased efficiency is attained: first, by the multiplication of these primary elements into larger areas; secondly, by the individual cell becoming more highly specialized, assisted by the development of the contiguous accessory components.

This differentiation may be displayed on their unattached border as a simple flat cell, or show a ciliated surface, or one or more tail-like appendages, which may be so highly developed and modified that these become a specialized receptor for gathering together definite stimuli of impressions. These are especially shown in the rods and cones of the retina, whose delicacy is so marked that they are surrounded by a soft fluid menstruum.

The eyeball shows a very variable size in the animal kingdom, though generally a proportional size to the animal in question. Yet in whales and in the elephant, while large in both instances, they are not, as compared to man, in proportion to the body. Again the sharpness of vision shows a certain proportion to the size of the eyeball as demonstrated by the acuteness of vision in the comparatively massive eyes of birds; although, at the same time, we are reminded of the acute vision of rodents. The eyes of animals

of a nocturnal habit are wont to be large; and man, in whom the eye has encroached upon the nasal space, to the detriment of that space, may be, in his not too remote ancestry, a progeny of an animal of nocturnal habit.

Shortly after the inception of embryonic life, before the complete full-formation of the total furrow or trough of the Longitudinal Medial Neural Groove, there appear, close to the so-called apex or cephalic end of this furrow, two transverse ridges, which invaginate, while at the same time the walls thicken, and on either side of the neural groove form a pouch from this thickened outer covering or ectoderm. These pouches are the hollow Primitive Ocular Vesicles of the primary fore-brain. These two tranverse grooves, evaginations, are seen within 24 hours in the embryo of the chicken, while in a human embryo they begin at the second or third week.

The primitive vesicles referred to are situated at first near the apex of the fore-brain. However, the fore-brain now takes on a very rapid growth, and, in its quick expansion, it apparently pushes back the optical vesicles, so that these become located near the mid-brain region, at the place where will be located the anterior floor of the infundibulum, or anterior floor of the third ventricle. This invagination grows outward by a multiplication of the superior layers of the epithelium, while the posterior end becomes narrower or constricted. The front end of this protruding rounded cleft is known as the Optic Vesicle, while the attached short constricted portion, attached to the medullary canal, is known as the Pedicle; this latter connection or stalk is the rudiment of the optic nerve, and although the optic vesicle is a protruded portion, it is essentially a portion of the brain itself, its structure identical with the primal part that remains behind, forming the intracranial structure.

At the time of the ectodermic protrusion, some cells from the Mesoderm are forced into the walls of this ectoderm which remain within the optic vesicle and the Optic Stalk, although, perhaps, only manifested as fragmentary protoplasm.

The anterior wall of the optic vesicle becomes convex from without inward, or "invaginates," so that the anterior wall almost

meets its posterior wall, converting the space between those two walls into a potential space, rather than an actual cavity. The optic cup now formed is thus lined with ectoderm; the forward wall is known as the Anterior Leaf, the posterior wall as the Posterior Leaf.

The hollow front end of this invagination becomes much thickened, and, in closing together, this thickened front end separates from the surrounding ectoderm, thus forming the primary lens. The primary lens sinks into the optic cup, as if a hard small ball were pushed into the wall of a soft elastic large ball, so that if it were forced further in, the outer walls of the larger ball would meet around it. This indentation forms the primitive Pupil forward, and the Optic Cleft posteriorly, while the space between the Lens and the Anterior leaf of the optic cup is the space to be occupied by the Vitreous (although at present it is only a potential space, as the lens now lies against the anterior leaf.)

The optic cleft begins to close at about the last of the fourth week, or the beginning of the fifth. The lens is, therefore, of epithelial character, which, from this time on has a slower growth than the rest of the anterior invagination. The posterior invaginated epithelium (or Ectoderm) eventually forms the Retina, or the secondary ocular vesicle, while the back wall, which thins down somewhat, becomes differentiated very early into layers, one of these finally becomes the outside pigment layer of the Retina and is completed about the seventh week.

The lens at first fills this whole cup, but, owing to the more rapid growth of the retinal layer, there is a space left, as the Lens is carried forward by its lateral connection with the edge of the cup. This space is the cavity of the Vitreous body, which is now formed. This all occurs up to, and about the 25th day. During this time, and before the stalk of the vesicle is closed, the Mesoderm, as stated before, has pushed into the ectoderm, and this Mesoderm, is the origin of the vitreous. Through this fissure also are seen some vessels, very minute at first, pushing their way into the interior of the Optic Cup. This vessel layer or Mesodermic layer, which is thrust forward, as it were, right into the substance of the Ectoderm, is the beginning of the Choroid; in fact the cleft

at the stalk is known as the Choroidal Fissure. This choroid (or mesoderm) pushes forward around the lens, where in front it divides or separates, leaving a cavity, the front wall of which forms the Cornea, while the back wall forms the Iris, which at first is a continuous membrane, connected across the Pupillary space by the Interpupillary Membrane. This membrane begins to be dissolved at the center and disappears at the end of the 7th month, after which the Small Circle of the Iris commences to be seen. Sometimes the Interpupillary membrane persists, *in toto* or in part; when it does so, it receives its blood supply from its marginal attachment. The pedicle cleft then closes off, and the vessels which are imbedded in the tube thus formed become the Central Vessels of the Optic Nerve.

The central vessels imbedded in the stalk of the optic nerve continue forward, and supply lateral branches to the vitreous and to the lens, where with the addition of vessels from the Choriod they form a dense network on the posterior surface of the Lens. This Vascular Plexus is known as the Tunica Vasculosa. The vessels leading up to the tunica vasculosa are known as Hyaloid Vessels from their central position in the Hyaloid Canal. These vessels all disappear before birth. The closure of the optic cup begins from the front backward and from the top downward, so that when, as sometimes happens, we note a congenital coloboma, the first appearance, which is typical of this phenomenon, is the failure of the iris curtain on its lower margin.

Now the mesodermic layer does something else in its journey around to the front of the eye, and that is, to form the Sclera. This is formed by a partial separation of the cellular elements, which separation occurs as far back as its original intrustion into the ectodermic tissue. In the brain this layer forms the dura mater.

The retina, as was noted, is the extension forward of the brain cells. Even these cells are highly differentiated, some of them purely nerve cells and some supporting or neuroglia cells. The retina grows rapidly and has a great multiplication of cellular tissue. Developmentally, it corresponds exactly to the three layers of the Embryonal Nervous System, so that the neurons of the

retina are characteristically developed like the neurons of the central nervous system. (1) The external or ependymal layer correspond to the outer nuclear layer, from which the rods and cones are derived, including the connecting outer molecular layer. (2) The middle, or mantel layer, correspond to the inner nuclear

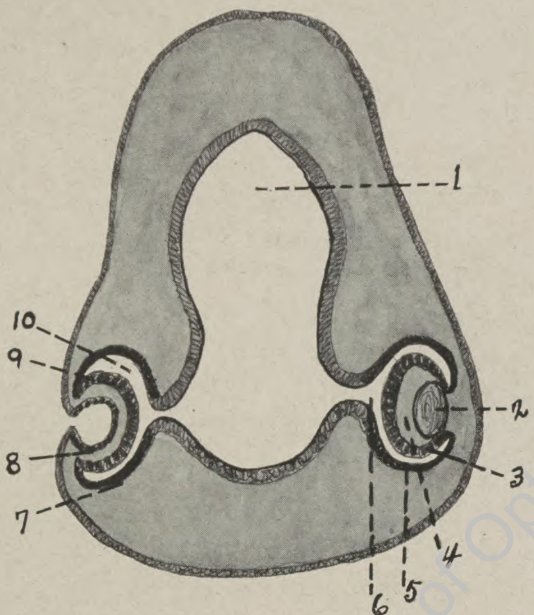


ILLUSTRATION OF EMBRYONIC DEVELOPMENT OF EYE.

(1) Cavity fore brain. (2) Lens. (3) Inner layer optic cup (Vesicle). (4) Cavity of vitreous body. (5) Outer layer optic cup. (6) Rudimentary optic nerve. (7) Outer layer optic cup. (8) Invagination to form lens. (9) Outer layer optic cup. (10) Optic vesicle.

layer, and its intertwined fibrillae. (3) The inner or Rand-Schleier layer corresponds to the ganglion cells and nerve fibers.

The rods and cones are developed from the outer nuclear layer, and are present in man at birth, while in animals that are born blind they are not fully developed until after birth.

The optic stalk, containing the optic nerve, forms at first without any definite nerve fibers present, but in its growth the

nerve is developed from the cerebral cells toward the retina, and these are known as centrifugal fibers, while those of origin from the ganglionic axones are known as the centripetal fibers. After the central longitudinal groove becomes grown together at its invagination, these lateral pedicle and nerve fibers meet here to form the chiasma, into which the nerve fibers are continued and crossed, so that the impressions from both retinae are finally registered as a single impression. In our description, thus far, we note that, of the three primary structures of the Ovum, called respectively the Mesoderm, or inner lining; the Entoderm, or central substance; and the Ectoderm, or outer covering; only two, the Mesoderm and Ectoderm, participate in the makeup of the Eye; from the Ectoderm is formed the Lens, the Retina, including the Pigment Coat.

The Optic Nerve, the Conjunctival Epithelium,

The Outer and Inner layers of the Cornea (Epithelium perhaps in both cases).

The Ocular Nerves.

The Nasal Ducts and Lacrimal Glands, and all the Glandular Structures of the Eye-Lids, including the Eye Lashes.

While from the Mesoderm we get, the Muscles of the Iris.

Vessels of the Choroid, and Supra Choroidea, the Sclera, and its Coverings,

Stroma of the Cornea, and its Stroma layers, Orbital Vessels and Orbital Muscles,—the Humors of the Eye, and the Bones of the Orbit.

It might be emphasized that the front layer, or epithelium of the cornea, is derived from the ectoderm and not from mesoderm, from which stroma of the cornea is derived. The union of the eyelids disappears naturally in man, shortly before birth, at the 6th month or later. In animals, this does not occur for some days after birth.

The Lacrimal Glands, and the other Glands of the Conjunctiva, are an Epithelial development from the Conjunctiva. They all begin development at about the 3rd month.

Non-development and poor development of ocular tissues may occur, or faulty development of muscles, as may often be indicated by congenital Ptosis, which is a not infrequent condition.

The analogue of the face seems to take a definite form about the beginning of the fourth week, at which time there may be noted five processes proceeding from the primordium of the membranous cerebral envelope. These are united in another four weeks, showing a primitive mouth, surrounded by the semblance of a potential face.

One of these processes, medial in position, the naso-frontal, with a bilateral similarly-indented outline, is flanked on either side by a latero-nasal and maxillary process, while below is the mandibular process. The naso-frontal process becomes the nose, while, the groove dividing the latero-nasal and maxillary process becomes the developing eye-lids, which groove is continuous to the more lateral situated orbits, while their proximal ends are the situations of the beginning lacrimal passages.

The face is joined together at about the end of the second month; some two weeks from then, the eyelids commence to take on form, now united by their approximated inner surfaces by the tissue that is to develop into the conjunctiva.

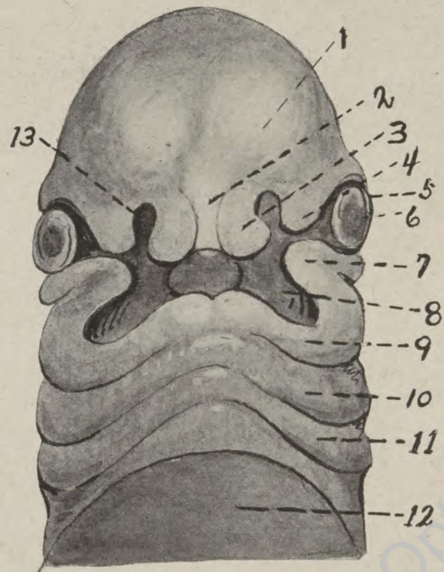
The upper lid develops simultaneously from the lateral and medial nasal processes, to finally merge at the middle of the upper lid, while the lower lid is derived from a single position from the maxillary process.

The ectoderm develops into the lid and its appendages, while the enclosed mesoderm that it carries forward develops the orbicularis muscles.

Development of Orbits: Ossification begins about the sixth or seventh week of all the bones in their several positions around the Orbit, from so-called Centers of Ossification. These are derived from membranous-like plates, which extend peripherally to unite with each other, in the center of which is an ossification center. Sometimes the union remains membranous for some years after birth, although the general form is completed at the sixth month. The surrounding sinuses are not developed until after birth. The Maxillary Sinus is the only sinus that is developed at birth, while the Lacrimal Canals are formed in the membranes very early.

The Frontal Sinus is first formed about puberty.

At birth the orbital opening is a striking feature, as regards size, in comparison with the other facial development; it is quite circular in outline, while the root of the nose is so imperfect that the lacrimal fossa seems to extend forward.



ANTERIOR VIEW OF HUMAN EMBRYO.

(1) Procencephelon. (2) Medial nasal process. (3) Globular process. (4) Lateral nasal process. (5) Eye. (6) Lens. (7) Maxillary process. (8) Stomatodaeum. (9) Mandibular arch. (10) Hyoid arch. (11) Third arch. (12) Pericardial region.

Fuchs Writes.

"In the growth of the body the orbit expands in proportion as the eyeball enlarges. If the eyeball is backward in its growth, and more especially if it is entirely destroyed in childhood, the dimensions of the orbit also remain smaller. If, therefore, in such cases it is desired later on in life to wear an artificial eye, we must content ourselves with one which is too small when com-

pared with the other eye." The mesoderm on either side of the neural tube shows three divisions early in embryonic life, and one of these groups is known as the Cephalic Myatome, which, when pushed out along the optical vesicle, is formed into the Ocular Muscles. These muscles are finally connected by the extensions of the cephalic nerves, which feed them as a group, the superior oblique and rectus lateralis having their own individual connecting nerves.

The first formation of the ciliary muscle appears when the foetus is 120 mm. long, while the completed development is not consummated until about the 7th or 8th month (Killel & Mall).

Seefelder shows that the anterior and posterior chambers are demonstrable in embryos of 23 mm.

Wofram recognizes Descemet's membrane in a foetus of 53 mm., this being completed at the ending of the fourth month, at which time Schlemm's Canal is indicated.

At the beginning of the sixth month the pectinate ligament, the angle of the anterior chamber, and the ciliary processes are demonstrable, and while I have accepted the opinions of the majority as to the origin of the orbital muscles, yet no satisfactory account has to this time been given.

"There generally is an asimetry to the face, making the right eye and orbit higher than the left, while the palpebral opening of the right is wider than the left, and lies further away from the nose."

The face in the infant, as compared with the cranium, is 1 to 8; two years, 1 to 6; five, 1 to 4; ten, 1 to 3; woman, 1 to 2½; man, 1 to 2.

The breadth of the face, as compared to the height, in infants at birth, is 10 to 4; in man, 9 to 8.

The orbit bears nearly the same proportion to the cranium in all ages, but at birth it equals one-half the height of face, while in adults it is less than one-third.

Orbital Index is a Mathematical Value, given by Broca, of the measurements of the skull Anthopologically considered. The measurements are called craniometry.

This index is figured from the ratio of the height of the base, as compared with the breadth, thus $\frac{100 \times \text{Height}}{\text{Breadth}}$

The Breadth is a line drawn from the junction of the Frontal with the Maxilla and Lacrimal, horizontally to the outer border of the Orbit. A large Index means a High Orbit, an index of 84 is called a Microseme; an index of 84 to 89 is called a Mesoseme; an index of above 89 is called a Megoseme.

In the average American the index is about 87; this, however, is subject to much variation, and is affected greatly by the overhang of the borders. An index of 105 is very high, while 70 is considered very low. Stelling, of Strassburg, advances a theory based upon the orbital index (which is disputed in whole or in part), that the compression of the globe of the eye by the superior oblique, in a low orbital index, predisposes to myopia, and vice versa.

These measurements, like all the cranial measurements, without doubt, show racial variations. The ones I described were Virchows' (horizontal and vertical). Another measurement for the orbital index is Broca's Diameters, which are from the greatest width dimensions, known as oblique diameters, which cross each other at right angles, the lines, however, being at a 45° oblique angle.

CHAPTER XIV.

Anomalies.

In our study of the anatomy of the eye we have endeavored to visualize a structure which should contain a full complement of wholly normal elements; or what we understand to be the essential components of a normal eye.

With due regard for the close approximation which one human eye displays to another in its anatomy, there are, nevertheless, no organs containing a greater diversity of conditions. It is, in fact, rare to find two eyes exactly alike even in the same individual. In our study of anomalies it is our purpose to discover deviations from the common rule, not on account of the morbid interest which such malformations always excite, but that we may at once recognize those deviations which represent anatomical changes, and may understand their significance.

Yet we must approach the discussion of this phase of anatomy in an attitude of diffidence, realizing that our definite knowledge of these conditions ceases when we have recognized them as such; of their causation we know little or nothing. No sooner have we found an apparent explanation for a given case than another instance will show a wide difference, or a total absence, of the plausible reasons advanced in the first case. Today, therefore, this field is one of sheer speculation, where all men are equal; for he who would pretend to explain why a cell begins or ceases to perform its function must certainly lay claim to an inspired intellect.

Any and all anomalous conditions may and do occur in children born of otherwise healthy parents. The phenomena of congenital abnormalities, besides being individual handicaps, always rise to an apprehensive state of mind in parents and relatives, who wish, if possible, to avoid such conditions in their progeny. The assurance by those, who are in a position to know our inability to explain these conditions, in a positive unequivocal manner, will add much to the satisfaction of the questioning family, even though some theorist may follow with an explanation as discordant as it is ingeniously untrue.

The inflammatory theories, except in cases of direct infec-

tions, afford no better explanation than the hereditary or possible remote consanguineous influences. The possibility of the eye anomalies being associated with other bodily infirmities is always present; on the other hand, in all abnormalities (and the eye is no exception) when one faculty is lessened or impeded there is often more than a compensatory development in the other faculties or organs.

Anomalies are divided according, firstly, as they relate to an inhibited growth, where the conditions are normal but not of sufficient size, and secondly, they represent imperfect development, where the conditions are malformed in one or more situations. These two conditions may be associated with each other, or appear singly, independent of any other findings.

By way of postscript it may be remarked that eye abnormalities have received the attention of all thinkers of all times. The remote allegorical or mythological writers, in ascribing these phenomenons to a supernatural power, have handed us down a nomenclature, like Cyclops, Janus, Cataract, Lens, and others, indicating to us their ancient theories of anatomy, which names we still use today as indicative of certain conditions.

In many instances, it is sufficient only to name the anomaly and the name in itself is self-explanatory of all the knowledge we have of the condition.

The congenital abnormal growths that may be found in the orbit or its contents are the many cysts, naevi or moles, which may affect every structure of this region, primarily or secondarily. These have the same significance here that they have in any other part of the body; however, the delicate structure of the surroundings may cause them to be of an earlier pathological import.

One of the most common varieties of cysts around the eye is a dermoid cyst, which contains all the constituents of an epidermal cell, in a varying degree of development; this cyst may be found in the skin, where of itself it would not necessarily be important, or in the conjunctiva, where its presence may irritate the cornea, or in the cornea itself; or, in fact, in any part of the orbital contents. In all these inner situations the size and the possibility of growth may make it of great importance. These

cysts, as a general rule, remain quiescent until puberty, at which time, coincidently with the pubic hair, they begin to grow. They occur, in the majority of cases, singly, without any other accompanying deformities—but may be multiple. In females, especially, there may be found a fibrous constituent in these masses, which are then known as lipodermoids. Teratomata are tumors of a cystoid character that contain particles of all the three primary blastodermic divisions of the ovum. These are exceedingly rare. Moles are sometimes found on the conjunctiva; when large they may cause an irritation to the cornea; while naevi may be of such an extent as to extend into the adjoining cranial cavity.

Congenital deformity of the lids shows as either a total absence or an incomplete development. These, like the cystoid growths and all other malformations around the eyes, may be found singly or in combination with one or a number of other eye anomalies, or may be combined with such bodily defects as cleft-palate, hair-lip, defective cranial development, and other physical imperfections. The condition of associated anomalies can occur in all malformations, therefore I will not, as a rule, again refer to it, with the citation of the separate deviations.

From our embryology we can understand the usual congenital defect of a coloboma of the upper lid, where there is a failure of the two lateral superior segments to fully unite at the center, or even an inhibited beginning of growth of the inferior lid. When the lids are entirely absent it is called *ablepharia*. There are cases in which the lids do not separate before birth, called *ankyloblepharon*. This may be partial or complete, unilateral or bilateral, and when complete there is often a mistaken diagnosis, as between two exceedingly rare conditions, one the above conditions and the other *anophthalmos* or total absence of the eyes.

There is quite a variety in the extent of lid defects which may be of more or less clinical importance. One of the lid anomalies, which in a Mongolian would be normal, is *epicanthus*, where there is a fold of skin at the medial angle of the eye. This may be of small or large extent. It is more or less present at birth, but the rapid growth of the bridge of the nose causes it soon to disappear. However, where this fold of skin in the anatomy persists,

as occasionally occurs in luetic children, it causes an appearance of strabismus, by its encroachment over the medial canthus. This may be a hereditary marking, in accord with the congenital marking of the nasal growth (which is of such remarkable frequency) and is derived from either branch of the family.

Conditions of the lids in which the palpebral fissure is too narrow or too wide, are known, respectively, as *Blepharo-phymosis* and *Lagophthalmos*. The eyebrows and lashes show quite a variety of shapes and sizes, and display various colors; these are not uncommon places to find various hairy filled cysts—perhaps often mistaken for true dermoids. There may be also, in these situations, supernumerary rows of the brows or the lashes, or a deficient growth of either, or display signs that a part has a deficient deposit of pigment (*piebald markings*).

The lid conditions enumerated above may cause the lacrimal excretory apparatus to be more or less prominent, or the excretory apparatus may in itself show abnormalities in its development, such as atresia, or displacement of the puncta, if present, or a total absence or duplication of one or both puncta or canaliculi. These are likely to be unobserved early, as tears are not secreted during the first weeks of life. There may be such abnormalities as absence or atresia of the canaliculi, sac or nasal ducts, the latter causing a very early dacryocystitis, which may be considered congenital in origin. These conditions occur from non-development or over-development of some of the surrounding structures as often as from some faulty condition of the lacrimal apparatus itself.

The muscles of the orbit are frequently involved as regards their insertion points and non-development of the muscles themselves, perhaps from a too lengthy development for the depth of the orbit, or additional secondary insertions that encroach on the muscular action, causing assorted conditions of atony or inhibition to the muscular action. Another very common cause of muscular anomalies, aside from the irregular development of the muscle itself, is found in the *irregular* development of the so-called secondary insertions of these muscles, where extra bands, or heavy reinforcements of the fascias, impede the movements in one way or another. These secondary insertions may take the form of

displaced muscle cells, which often develop sufficiently to be known as super-numerary muscles. These muscular bands are occasionally quite irregularly placed in among the fibrous tissues, or are offshoots of the extrinsic muscles themselves.

Lateral as well as superior ptosis may occur, all of which conditions may be associated with other visual deformities. These constitute a congenital condition in many instances and are associated with defective nerve development; it may be unilateral or bilateral; in either case there needs a close study of all the involved complications in considering the possible correction. Not only is the lid involved but always in the congenital types the recti muscles are affected, and there is generally a poor vision. Lues and struma of various degrees may be looked for. The operations for the correction of these ptosis cases are so many, and often so ingenious, that one operation usually does not entirely suffice for all the cases, and the selection of the manner of procedure is dependent often on the case in hand.

Often in microcephalus the lacrimal gland fails to develop fully, but this is of rare occurrence.

The anomalies of the nerve and arterial supply that are discovered post mortem are quite as frequent in the orbit as in other positions. Occasionally, the non-development of the ocular vesicle will result in a total absence in the eyeball, *crypt ophthalmia.* This inhibition may occur at the brain itself or in the future orbit. Cases have been reported by some very good anatomists describing this condition, so that the fact is indisputable.

The repressed growth of eyeballs is found in various phases in microcephalous or normal heads. They are often bilateral or in different stages of development on the different sides, one eye showing a more advanced growth than another, so that all the parts are further advanced on one than the other side. There is a condition which accompanies these various phases of ocular maldevelopment that should perhaps have a chapter to itself, called *Nystagmus,* which is a rhythmical oscillation of the eyeballs, usually in a horizontal plane. This may be so marked that no one would overlook it, while in other cases it is so slight that it will take close scrutiny to make the discovery.

In cases of inhibited growth of the eyeball, the normally thin scleral envelope is then much thinner, so that the internal or ocular pressure causes a bulging forward of the cornea, known as *keratoconus,* which assumes, in its different degrees of bulging, various shapes. Again, the pressure will cause a posterior bulging, manifested by a cyst-like appendage of scleral tissue. These cysts may be single or multiple. Again, the whole eyeball will take on a rounded swelled condition, called *buphthalmus.* These various swellings are the precursors of so-called *infantile glaucoma,* which is a true glaucoma showing that haziness of the cornea and deep cupping of the disk, and other symptoms, which are found in all glaucomas, with perhaps the difference that the anterior chamber is deepened instead of being more shallow. These conditions may end in a spontaneous recovery, so that surgical interference had better be delayed. In these cases anterior or posterior synechia may occur.

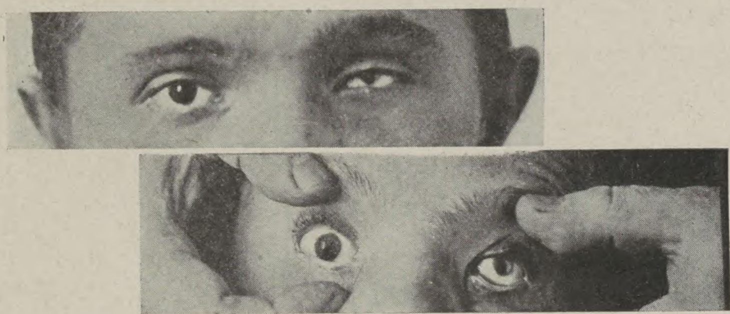
There is another condition of inhibited growth in the eyeball called coloboma (meaning maimed) where the growth of a part is not fully consummated. The wherefore is a question, not only as to the reason, but as to what was involved at the time of the failure to close. It is supposed by some to be a failure of closure of the choroidal cleft. These colobomas may be single, affecting only one situation in the development, or may affect several structures within the eye. They may be unilateral or bilateral, and may be of variously advanced states in the two eyes; or they may be complicated with any of the various deformities which are taken up in this chapter.

The iris, when showing a congenital coloboma, displays this imperfection usually on its inferior side, more medial than lateral. This is so often found here that it is almost pathognomonic, although it occasionally may be found superiorly.

The choroid may show this condition at one or more situations; it is usually found near the macular region, or it may extend into the disk, involving the nerve head, or be associated with a coloboma of the retina. It is discoverable, generally, on examination with an ophthalmoscope, by the appearance of the sclera, showing in white patches on the fundus field. There may

be an associated coloboma of the lens, where the displacement may occur in any of several directions. These colobomata may all be associated conditions.

The pupil may be so materially displaced from the normally near-central position that it will approach a coloboma in appearance. There may be, however, several openings in the iris that will take oval or angular rounded appearances, and so constitute



ANOMALIES.

The anomalies in this case, boy aged sixteen, are typical of a coloboma of the iris, displaying the notch at the lower border in each iris. In the top picture you will note the difference in size of the palpebral fissure, also the more marked ptosis on the left side. The width of the right cornea is nine milimiters, while the left is six milimiters, with a corresponding diminished palpebral opening. In picture No. 2 different colors of the irides are noticeable, the smaller eye having the lighter color, while the forcible opening of the left eye shows the epicanthus exaggerated. This is a son of a large family, the preceding and following children showing no signs of congenital defects. In the section of Roentgen Photograms are shown an anterior and both lateral views of the accompanying lessened growth of the orbits.

supernumerary pupils, these no doubt occurring from foetal synechias in the iris tissue itself, or irregular absorption of the interpupillary membrane, or posterior synechias to the lens capsule. They receive, according to the appearance, the names of *corectopia, diplocoria* or *polycoria.*

There are certain opacities of the lens, occurring mostly bilaterally, known as congenital cataracts, which are usually of the polar or lenticular variety. The lenticular varieties take on quite a variable design, so that some may appear stellate, with well

marked design of a rosette and a variable number of prongs, while others are mere clots and lines following the lens fiber course. When of a polar variety, they may be either anterior or posterior polar, either centrally located or away from the center.

The cornea may be congenitally opaque, partially or entirely, and associated with other ocular malformations. It also may show in this connection a variation in size due to these malformations; or, in eyes that are otherwise normal, the cornea may be of greater or less diameter.

There are conjunctival dermoids occurring at the limbus, that may be considered corneal growths from their close approximation.

There occurs a congenital interstitial keratitis in which there may be usually elicated a well-marked luetic history; or several children may be affected in the same family, which condition I have referred to under the heading, Cornea.

The persistence of the hyoloid vessels may occur and be so well defined as to interfere with vision. The vitreous in the embryo is of a cellular composition and opaque, which like the hyoloid vessels becomes transparent before birth; in fact, at about the sixth month. Often, however, these opacities can be observed within the vitreous as transparent spots or tufts named *muscae volitantes,* which move with or follow the eye movements. However, they may be present without their existence being discovered by the possessor. They are usually found in myopic eyes. Again there may occur such marked deviations of the central arteries and veins that they would be considered almost malformations; yet the circulation is not interfered with.

There is a condition where the lateral anterior branches of the central vessels pierce the cribiform plate at the edge of the disk and come forward and are spread on to the field of the retina, often spoken of as the vessels of the short cilliaries, or cilio retinal arteries from the vascular circle of Zinn coming forward, so that there are two arterial circulations referred to as being seen by the ophthalmoscope. The fact that these vessels on pressure show the same arterial pulse that we can elicit occasionally from the central vessels, and that they possess those peculiar endings which are

distinctive of the central vessels, makes them undoubtedly branches of the central vessels which have pierced the plate, and they should be known as anterior lateral central vessels instead of anterior cilia retinal vessels.

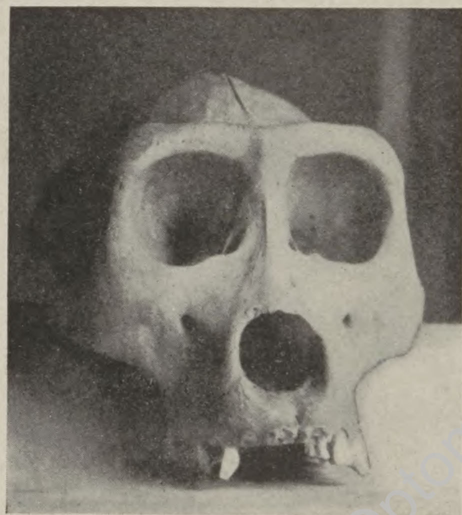
I know of no subject that is more engrossing than the deposit of pigment, from a morphological standpoint as well as its individual relationship to the eye in particular; and in this statement I am not in the remotest sense alluding to it from any standpoint except that of anatomy and its anatomical distribution. (I have, in the description of the iris, referred to it in the kindest and more than generous manner as to my opinion as to its diagnostic value in general disease.)

Retinitis pigmentosa is found, according to Shoemaker of Philadelphia, 1909, in his work on that subject, to be flakes of pigment that are displaced into the retinal tissue, accompanied by changes in the choroid, optic nerve and blood vessels, and other parts of the visual apparatus; his observations being taken in an institution for the deaf and dumb where a large proportion of these cases showed this anatomical defect.

The influence of consanguineous marriages and their peculiar relation to offspring cannot well be eliminated; however, that may be, it is a fact that this is a condition which is present at birth and is usually accompanied by poor vision, especially at night. However, I saw, in company with one of my colleagues, one well-marked case, where the patient, a man of middle age (57 years) had been a proofreader for more than a quarter of a century, reading many hours daily. The fact that there totaled seventeen cases in the deaf mute asylum to which Dr. Shoemaker was attached is a remarkable incident in itself, showing to a close observer the possibility of its frequency. Fuchs thinks this a degeneration of the retinal pigment, allowing the choroidal pigment to show through the degenerated retina, and calls it a pigmentary atrophy of the retina. There may occur a pigmentation of the disk, sometimes referred to as medulated fibers showing at the disk head.

A not very uncommon condition is *heterochromia* or a difference in the pigmentation of the irises, either of one, or of both,

partially or entirely. These are seen so frequently as not to excite much attention. There is one phase of this irregular deposit of pigment, however, which is of importance, and to which I will simply refer, namely, that the lighter of two eyes, when one is of quite different color from the other, is very apt to take on in time an inflammed condition, cataract, or even a glaucoma, perhaps because, as the two eyes are not evenly protected, the irritation



ANTERIOR PHOTOGRAPH OF SKULL OF GORILLA.

Note the orbital height greater than the horizontal measurements, the distance away from the orbit of the infra orbital foramen, the narrow apex of the orbits, with the small development of the superior orbital fissure, and the well developed naso lacrymal canal with the marked anterior marginal tubercle. Anatomical Museum, University of Chicago.

caused by the excessive penetration of light in the less pigmented eye brings about inflammation. There is an absence of physiologic pigmentation called *albinism,* which affects the whole system, and which was first noticed in the negro races of ancient Albania. This has a peculiar manifestation in the eyes. It is first noticeable by the natural photophobia, and, on examination, shows the want of pigment, especially in the choroid, so that when

seen with an ophthalmoscope the choroidal vessels will be well laid out against a white fundus. There is nystagmus, which in this case is nature's way of trying to relieve, if possible, any one spot from being exposed too long to the action of light. It is also generally attended by poor sight, with myopia and its consequences. Some of these cases, in early youth, or at puberty, or even later, take on

PHOTOGRAPH OF THE FACE OF AN ACROMELGY.

Showing the orbits normal, except the superior wall which, on account of the great thickening of the frontal bone, presents an appearance that is so marked in the larger apes, where the superior margin is so bluntly rounded as to obscure its landmarks. Note the flattened oblong contour of the orbits in this case, the well marked lateral sphenoidal tubercle, and the distance from the front of the anterior ethdoidal foramen. From the Anatomical Museum, University of Chicago.

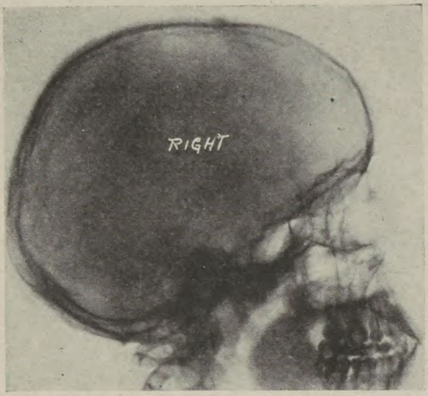
a sudden pigmentation; but this favorable termination cannot be assured to any one, however much it may be hoped for.

The fact that the pigmentation, from birth to several years of age, changes generally to a darker shade, is one of the phases of this subject we do not understand. These Albinotic people are not all offspring of consanguinity; and while, perhaps, of nervous

origin, the hereditary theory does not fully explain the phenomenon, although it may occur apparently through heredity, skipping one generation, or through lateral branches of the family, which is characteristic of hereditary histories.

There is a condition of over-pigmentation which is quite as difficult to explain; these areas, which in the eyes of a horse are normal, may frequently occur on the scleral surface of man, generally in the region of the anterior emissaria; these are usually found in the negro and the darker races. When found, there is no pathologic significance to be attached to them, as they represent simply an abnormal deposit of pigment and have not been proven to tend toward malignancy.

Hrdlicka in his current series of Psysiological Anthropology of Old Americans, 1922, says, in speaking of distribution of pigmentation, "There are 'Reds' in which the whole system participates in this phenomenon (meaning coloration). The eyes are pale, light blue or greenish, the skin is akin to the rosy skin of the albino, the breast areola is devoid of pigment, the mucous membranes are light red."

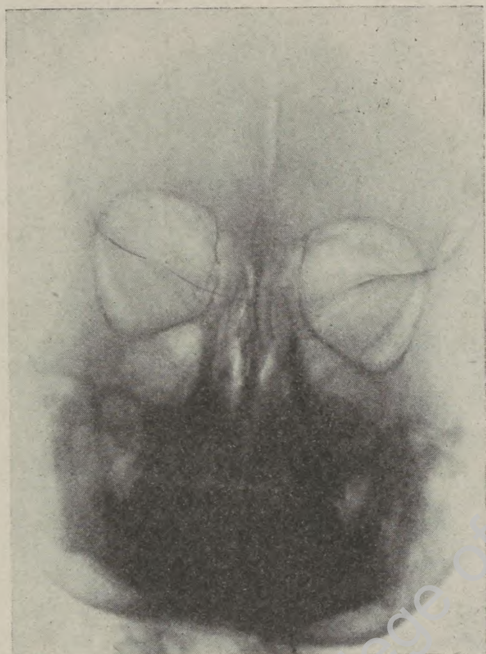


ROENTGEN-PHOTOGRAMS.

Right and left view of orbits in case of coloboma of boy shown in section on anomalies. Supplied by National Pathological Laboratories, Inc., Chicago.

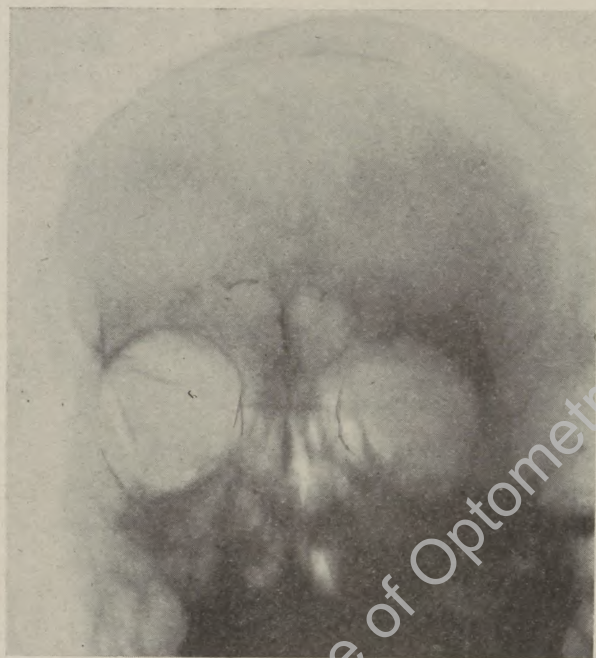
ROENTGEN-PHOTOGRAM.

Boy, age sixteen, showing small development of contour of orbits in a case of coloboma congenitalis. Illustration and further description of this case in section of anomalies. National Pathological Laboratories, Inc., Chicago.



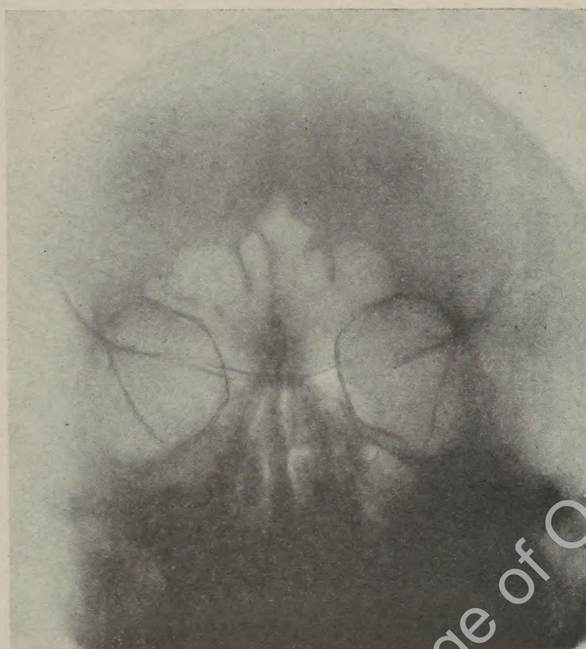
ROENTGEN-PHOTOGRAM.

Child of six years, showing size and contour of orbits, the absence of the frontal and ethmoidal sinusus at that age and the well developed maxillary sinus. Laboratory of North Chicago Hospital.



ROENTGEN-PHOTOGRAM.

Man, showing contour and size of orbits and the relations of the well developed frontal and ethmoid sinusus. Laboratory of North Chicago Hospital, 1922.



ROENTGEN-PHOTOGRAM.

Woman, showing contour and size of orbits, the frontal and ethmoidal sinusus well developed, and their intimate relations. Laboratory of North Chicago Hospital.

CHAPTER XV.

Weights of the Eyeball.

	Adults.	13 to 15 yrs.	1 year.	New Born.
Sappey	7 to 8 grams			
Teste	7.14 grams			
Weiss	7.45 grams	5.87 to 6.50	4.05	2.25
Fuchs	7. grams			
Schafer	6.5 grams			

Eye Ball Diameters.

	Optic Axis Diameter.	Transverse Diameter.	Vertical Diameter.
Sabotta-McMurtrich......1909..	24.	24.	23.5
Quains..........................	24.	24.5	23.5
Grays..................1920..	22.9	25.4	22.9
Morris..................1894..	24.5	23.9	23.5
Saltzman...............1912..	24.6	23.7	23.57
McAllister.............1889..	24.27	24.25	23.65
Debierres..............1890..	24.	23.5	23.
Leidys..................1889..	25.4	25.4	25.4
Gerlack.................1891..	24.2	23.8	23.5
Testut..................1894..	25.26	23.5	23.
Vierort.................1893..	24.	24.3	....
Rauber and Kruse........1893..	24.27	24.32	23.6
Merkel..................1887..	24.3	23.6	23.3
Sappey..........................	24.2	23.6	23.2
Rauber..........................	24.2	24.1	23.5
Tiedermann......................	23.6	22.2	22.2
Huschke.........................	22.5	22.5	22.0
Bruche..........................	24.5	24.9	24.4
Jälzet..........................	24.3	23.6	23.4
Volkman.........................	24.7	24.2	....
Heuber..........................	24.	23.5	23.1
Krauser.........................	24.1	24.1	23.7
Trereranus......................	23.4	24.7	24.7
Weiss...........................	23.85	24.43	23.85

Emmert's Table of Selected Skulls, in "Auge and Schadel," Berlin, 1880.

	Males 20 to 67 years.	Females 23 to 67 years.	Children 10 to 17 years.
Width	41.6	39.8	34.3
Height	34.	33.6	29.2
Depth	39.8	39.4	34.75
External wall	46.4	46.	39.4
Internal	41.4	40.3	36.
Outer edges orbits	99.7	96.	80.8
Axis orbits	60.	58.3	48.1
Angle facial angle make with each other	147.	146.5	144.6
Angle orbital axis	43.4	44.7	42.4
Angle bet. external orbital walls	89.9	89.9	87.4

Females

Sappey's tables of the diameters and curving measurements of the adult eye-ball was very carefully done. He found that there was such a similarity of the two eyes, that he used but one in each subject examined These measurements were taken within one day after death.

	Right or Left	Age	Optic axis	Trans-verse	Verti-cal.	Int. oblique below inwards	Int. oblique below outwa'd	Optic nerve curved to int. side cornea.	Optic nerve curved to ext. side cornea.
1	R	18	23.	23.2	23.	23.4	23.4	26	33
2	R	25	23.4	22.8	22.5	23.3	23.3	25	32
3	L	28	24.	23.3	23.3	23.5	23.8	26	33
4	R	30	23.5	22.6	22.6	24.1	23.8	26	34
5	L	35	23.9	23.1	23.1	23.7	23.7	28	33
6	L	40	25.	23.6	23.6	24.3	23.7	29	34
7	R	50	24.3	23.8	24.	24.6	25.1	27	33
8	L	66	26.4	27.1	23.4	25.7	25.3	32	37
9	L	69	23.6	23.5	23.	25.4	25.3	28	33
10	L	72	22.9	22.8	22.3	23.5	23.6	27	34
11	L	74	23.4	23.3	22.6	23.8	23.3	28	32
12	L	81	23.2	22.5	22.5	23.1	23.4	25	31
Averages..			23.9	23.4	23.	23.8	23.8	27	33.2

Males.

Right or Left		Age	Optic axis	Transverse diameter.	Vertical diameter.	Outer oblique from below in.	Outer oblique from below out.	Dis. curved from optic nerve to int. side cornea.	Dis. curved from optic nerve to ext. side cornea.
1	R	20	24.8	23.3	23.8	23.7	23.9	28	33
2	L	22	23.6	22.8	22.5	23.5	23.5	26	33
3	L	25	24.2	22.4	22.2	23.5	23.6	27	34
4	R	26	24.3	23.4	23.4	23.7	23.5	27	33
5	R	31	24.7	25.9	22.8	24.4	24.8	30	37
6	L	35	26.3	25.4	25.2	....	....	31	39
7	L	45	25.2	24.6	24.	24.8	25.	29	37
8	R	50	24.4	23.9	25.8	23.9	24.5	27	35
9	L	59	25.	23.8	23.4	24.3	24.3	27	36
10	L	63	24.	24.	24.	25.5	24.7	28	35
11	L	67	24.9	24.9	24.	....	....	28	34
12	L	70	24.3	23.1	24.5	24.6	24.	25	32
13	L	75	24.8	23.9	23.8	24.6	24.5	27	35
14	L	79	24.7	23.6	23.6	24.2	25.5	27	35
Averages..			24.6	23.9	23.5	24.1	24.2	27.5	34.5
Average both sex.			24.2	23.6	23.2	23.9	23.9	27.3	33.8

Four of above observed 1 to 4 hours post mortem.

Motais and Weiss make an interesting notation, showing the anterior insertions of the recti muscles a variable distance away from the limbus, measuring on either angle of the insertions, the averages are:

		"Weiss" new born to 16 years.	"Motais" adults.		
		Aver.	Aver.	Max.	Min.
Rectus Sup.	Temp........	8.64	11.	12.	7.
	Nasal........	7.14	6.5	9.	5.3
R. Inferior	Temp........	8.75	8.	10.5	7.
	Nasal........	6.30	5.5	7.5	4.5
Internus	Upper........	5.81	5.5	7.75	4.
	Lower........	6.33	7.	9.5	4.5
Externus	Upper........	7.11	7.	10.5	5.5
	Lower........	7.07	6.7	9.25	5.5

Schäfer's Tables.

Greatest thickness sclera, choroid, and retina together	1.4
Thickness sclera posterior	0.8
Thickness sclera equator	0.4
Thickness cornea center	0.8
Dist. mid. outer surface cornea to front lens	3.6
Same in fully accommodated eye	3.2
Ant. post. diam. lens	4.
Transverse diam. lens	9.1
Greatest thickness of ciliary body	1.1
Thickness of iris	0.4
Length radius curvature ant. surface of cornea	7.8
Radius post. surface sclera	12.5
Radius curv. anterior surface lens	10.0
Same fully accommodated eye	6.
Radius posterior surface	6.
Same fully accommodated eye	5.
Dist. middle post. surface lens from retina	15.0
Dist. between center disk to center of fovea	3.5

Field of Vision

	Degrees.		Degrees.
Above	70	Below	60
Above and out	60	Below and in	55
Outward	90	Inwards	55
Below and out	85	Above and in	55

"Luciani."

Composition of Aqueous—

"Sp. Gravity 1.0034 to 1.0060 ('Schäfer 1.077'). Contains .86% Solids of which .045 consists of protein, albumen and globulin. Normal fluid of eye contains no fibrinogen, but sugar up to .03—.05%. Its osmotic pressure is higher than that of blood."

Measurements by Different Authors.

Thickness cornea center	0.45 to 1.37 mm.
Depth anterior chamber	2.90 to 4.09 mm.
Thickness lens	3.03 to 4.43 mm.
Dist. back lens to fovea	14.75 to 15.00 mm.
Radius curvature corneal surface	6.852—8.151
Radius curvature ant. lens surface	2.9 —4.09
Radius curvature post. lens surface	5.13 —8.49
Outer Epithelium Cornea center	.045 mm. thick
Outer Epithelium Cornea periphery	.080 mm. thick

Weiss—Dimensions New Born in 14 Observations. Showing Range of Variations.

	Optic axis.	Transverse diameter.	Vertical diameter.
Maximum	17.5	17.75	17.
Minimum	15.75	14.5	14.5
Average	16.40	16.	15.40

Adults.

Distance limbus to exit. vortex veins.	Upper vortex.		Lower vortex.	
	Outer.	Inner.	Outer.	Inner.
Emmetropes	20.2	19.3	17.4	18.
Myopes	20.5	19.4	17.1	17.
Hypermetropes	17.6	17.4	14.9	16.

Adults.

Inferior oblique—Average distance from Fovea, 3 min. Henley says, 2 min. Werther says, 2.2 min.

Distance behind equator of vortex veins.	Upper vortex.		Lower vortex.	
	Outer.	Inner.	Outer.	Inner.
	8.2	7.3	5.4	6.

Adults.

Length in sclera of vortex veins.	Upper vortex.		Lower vortex.	
	Outer.	Inner.	Outer.	Inner.
	4.6	3.3	3.	3.

Fuchs' Tables.

Rectus—Insertion distances from limbus.	Internus			Inferior			Externus			Superior		
	Mn.	Mx.	Avr.	Mn.	Mx.	Avr.	Mn.	Mx.	Avr.	Mn.	Mx.	Avr.
Emetropes.....	4.3	6.7	5.5	5.3	8.2	6.5	5.3	8.2	6.9	6.8	9.	7.7
Myopes.......	4.8	6.2	5.5	6.3	8.5	6.9	5.8	8.2	6.9	6.3	9.7	7.7
Hypermetropes.	....	....	5.2	....	....	6.	....	....	6.4	....	....	7.1

Width anterior rectus tendons.	Internus			Inferior			Externus			Superior		
	Mn.	Mx.	Avr.	Mn.	Mx.	Avr.	Mn.	Mx.	Avr.	Mn.	Mx.	Avr.
Emetropes.....	8.8	12.	10.3	7.8	13.2	9.8	8.5	10.2	9.2	8.5	13.2	10.6
Myopes.......	9.8	13.7	11.4	8.8	13.2	10.4	8.8	12.7	10.1	9.	12.7	9.9
Hypermetropes.	....	....	10.2	....	....	9.6	....	....	9.1	....	....	9.9

Width Superior oblique tendon bulbar insertion.	Min.	Max.	Aver.
Emetropes..........................	7.5	12.7	10.7
Myopes.............................	6.8	14.	9.6

Width Inferior oblique tendon bulbar insertion.	Min.	Max.	Aver.
Emetropes..........................	7.	11.2	9.4
Myopes.............................	8.3	14.7	10.6

Distance Inferior oblique to optic nerve.	Min.	Max.	Aver.
Emetropes..........................	3.8	7.5	5.2
Myopes.............................	4.8	11.5	7.1

Showing Deviations As Regards the Range of Figures in Many Measurements

NEW BORN.	INSERTION FROM LIMBUS.		
	Aver.	Max.	Min.
Rectus Internus	3.6	4.3	3.
Externus	4.9	5.75	4.
Inferior	5.	5.5	4.
Superior	5.8	7.	5.
ADULTS.			
Rectus Internus	5.85	6.75	5.
Externus	6.75	7.75	6.25
Inferior	6.85	7.5	6.
Superior	8.01	9.	6.75

Optical Measurements.

Luigi Luciani & Helmholtz.

Refraction Index.

Cornea 1.3771
Aqueous 1.3374
Capsule lens .... 1.3599 }
Outer coat lens .... 1.3880 }
Middle coat lens .... 1.4060 } Later, 1.43
Nucleus .... 1.4107 }
Vitreus 1.3360
Radius Curvature Cornea .... 7.82 mm.
Radius Curvature Ant. surface Lens .... 10.00 mm.
Radius Curvature Post. surface Lens .... 6.00 mm.
Dist. Anterior lens from Cornea .... 3.6 mm.
Dist. Posterior lens from Cornea .... 7.2 mm.
Diam. of cone 2.6 μ.

Fovea 1.5 across subtends an angle of 3 6/7 with Geometrical axis of the eye-ball or optic axis.

RACIAL CLASSIFICATION OF SKULLS

Flower, Wm. H.—"Classification of Skulls" in Royal College of Surgeons.

MEGASEMES...	Japanese American Indians of all tribes including a large proportion of ancient Peruvians Andamaneses Mixed Polynesians Eskimos
MESOSEMES...	Mixed Europeans including English Ancient Egyptians Indian Races of India Chinese Burmese Malays Fijians African negroes generally
MICROSEMES..	Australian Bushmen Guanchias

Roof of the Orbit.

Broca, in Topinard's Anthropologie, shows that the average length of the roof; optic foramen to superior margin.

Australians	56.2	Paupuans	55.7
Eskimos	57.7	Spanish	47.2
Usbecks	57.5	Dutch	49.8
Chinese	55.5	Arabians	50.3
New Caledonians	55.5	French ancient	49.6

French today 50.9

Merkel, Bonnet & Weiss, 1897.
Measurements.

	New Born.	20 days.	2 months.	3 months.	11 months.	1 year.	$1\frac{3}{4}$ years.	$2\frac{1}{2}$ years.	$3\frac{1}{2}$ years.	$4\frac{1}{2}$ years.	6 years.	7 years.	8 years.	9 years.	13 years.	15 years.	Adults, average.
VOLUME IN CC....	2.185	2.310	2.600	3.340	2.850	3.880	5.000	4.280	5.420	5.600	6.180	5.200	.....	5.340	5.700	6.250	7.180
EYE-DIAMETER AVERAGES:																	
Optic Axis.......	16.4	16.75	17.	18.5	17.5	18.3	20.	19.	21.5	21.	21.3	21.5	21.	20.75	22.	22.3	23.85
Horizontal.......	16.	16.75	16.5	19.	18.	20.	20.5	20.	21.	21.5	21.3	21.25	21.5	20.7	22.	22.	24.43
Vertical.........	15.4	16.	17.	18.5	18.	19.75	20.	20.	22.	21.	21.3	21.	21.3	20.75	21.	22.5	23.70
Variations in above measurements, 1 to 1.5 m m. all through.																	
AVERAGE WIDTH GLOBE TENDONS:																	
Superior Rectus..	6.95	6.	7.	9.	7.3	8.	96.	7.	10.75	10.	9.5	10.5	8.	9.5	11.75	7.	10.75
Inferior Rectus...	6.25	7.	7.	9.	7.	9.	9.	8.5	10.25	9.5	8.	10.5	8.	9.75	9.6	10.	10.35
Internal Rectus..	7.35	8.25	8.	8.5	8.	9.5	8.5	9.75	10.5	10.25	9.75	10.75	9.	10.5	10.	10.	10.76
External Rectus..	5.85	6.75	6.	8.5	7.	8.3	8.5	8.	9.5	10.25	8.	9.	8.6	9.	8.	9.	9.67
Superior Oblique.	6.4	5.	8.	8.	5.5	7.	7.	7.5	8.5	9.	6.75	7.75	6.5	11.	9.5	9.5	10.15
Inferior Oblique..	6.5	5.5	6.5	7.	6.	8.	8.3	7.5	8.5	9.6	10.5	8.	8.75	9.	7.3	7.6	9.55
Variations in measurements 1 to 1.6 m m. in all the widths.																	
AVERAGE DIST. OF MUSCLE INSERTIONS FROM LIMBUS:																	
Superior Rectus..	5.8	5.75	6.5	6.75	6.	7.	7.5	7.	8.	2.5	7.5	6.75	7.3	8.	7.	8.25	8.1
Inferior Rectus..	5.	5.25	5.3	5.75	5.	5.	6.5	6.25	6.75	5.	7.	6.5	6.6	7.5	7.	8.	6.85
Internal Rectus..	3.6	3.75	4.	4.5	3.5	5.	5.75	5.	5.	5.	5.	5.	5.25	5.	5.3	5.5	5.85
External Rectus..	4.9	5.	5.	6.	5.5	6.	6.	6.	7.	6.6	6.5	6.75	6.25	7.	6.25	7.25	6.75

Variations in all measurements 1 to 1.5 m m. greater or less, except internal rectus seems more constantly placed.

Glossary of B. N. A. Terms.

Aditus orbitae.	*Orbital opening.*
Aequator.	*Equator.*
Aequator lentis.	*Equator of lens.*
Ala magna.	*Large Wing.*
Ala parva.	*Small Wing.*
Ampulla ductus lacrimalis.	*Dilatation of lacrymal duct.*
Angulus iridis.	*Iris Angle.*
Angulus oculi lateralis.	*Outer Angle of Eye.*
Angulus oculi medialis.	*Inner Angle of Eye.*
Annulus conjunctivae.	*Conjunctival Ring (Circle).*
Annulus iridis major.	*Large circle of iris.*
Annulus iridis minor.	*Small circle of iris.*
Annulus tendineus communis (Zinni).	*Common tendon of Zinn.*
Apparatus lacrimalis.	*Lacrymal apparatus.*
Arcus superciliaris.	*Supercilliary arch.*
Arcus tarseus inferior.	*Lower tarsal arch.*
Arcus tarseus superior.	*Upper tarsal arch.*
Arteriae.	*Arteries.*
A. centralis retinae.	*Central artery of Retina.*
A. dorsalis nasi.	*Dorsal artery of nose.*
A. ethmoidalis anterior.	*Anterior ethmoidal artery.*
A. ethmoidalis posterior.	*Posterior ethmoidal artery.*
A. frontalis.	*Frontal artery.*
A. hyaloidea.	*Hyaloid artery.*
A. lacrimalis.	*Lacrimal artery.*
A. meningea anterior.	*Anterior meningeal artery.*
A. ophthalmica.	*Ophthalmic artery.*
A. supraorbitalis.	*Supra orbital artery.*
Aa. ciliares anteriores.	*Anterior ciliary arteries.*
Aa. ciliares posteriores breves.	*Posterior short ciliary arteries.*
Aa. ciliares posteriores longae.	*Posterior long ciliary arteries.*
Aa. conjunctivales anteriores.	*Anterior conjunctival arteries.*
Aa. conjunctivales posteriores.	*Posterior conjunctival arteries.*
Aa. episclerales.	*Episcleral arteries.*
Aa. palpebrales laterales.	*Outer (lateral) palpebral arteries.*
Aa. palpebrales mediales.	*Inner (medial) palpebral arteries.*
Arteriola (Venula) macularis inferior.	*Inferior macular artery (vein).*
Arteriola (Venula) macularis superior.	*Superior macular artery (vein).*
Arteriola (Venula) nasalis retinae inferior.	*Inferior nasal artery (vein) of retina.*

Arteriola (Venula) nasalis retinae superior.	*Superior nasal artery (vein) of retina.*
Arteriola (Venula) retinae medialis.	*Inner (medial) artery (vein) of retina.*
Arteriola (Venula) temporalis retinae inferior.	*Inferior temporal artery (vein) of retina.*
Arteriola (Venula) temporalis retinae superior.	*Superior temporal artery (vein) of retina.*
Axis lentis.	*Axis lens.*
Axis oculi externa.	*External axis of Eye.*
Axis oculi interna.	*Internal axis of Eye.*
Axis optica.	*Eye axis.*
Brachium quadrigeminum inferius.	*Inferior Quadrigeminum Arm.*
Brachium quadrigeminum superius.	*Superior Quadrigeminum Arm.*
Bulbus oculi.	*Eye Ball.*
Camera oculi anterior.	*Anterior chamber of Eye.*
Camera oculi posterior.	*Posterior chamber of Eye.*
Canalis caroticus.	*Carotid Canal.*
Canalis hyaloideus.	*Hyaloid Canal.*
Canalis infraorbitalis.	*Infra-orbital canal.*
Canalis nasolacrimalis.	*Naso-lacrimal canal.*
Capsula lentis.	*Lens capsule.*
Caruncula lacrimalis.	*Lacrimal caruncle.*
Cellulae ethmoidales.	*Ethmoidal cells.*
Choroidea.	*Choroid.*
Ciliaris.	*Ciliary.*
Circulus arteriosus major.	*Large arterial circle.*
Circulus arteriosus minor.	*Small arterial circle.*
Circulus vasculosus n. optici (Halleri) (Zinni).	*Vascular circle of optic nerve (of Zinn) (of Haller).*
Colliculus inferior.	*Inferior colliculus.*
Colliculus superior.	*Superior colliculus.*
Commissura palpebrarum lateralis.	*Outer lid angle.*
Commissura palpebrarum medialis.	*Inner lid angle.*
Conjunctiva.	*Conjunctiva (mucous membrane).*
Cornea.	*Cornea.*
Corona ciliaris.	*Ciliary wreath.*
Corpora quadrigemina.	*Quadrigeminal Body.*
Corpus.	*Body.*
Corpus adiposum orbitae.	*Body fat of orbit.*
Corpus ciliare.	*Ciliary body.*
Corpus vitreum.	*Vitreous Body.*
Cranium.	*Skull.*
Crista frontalis.	*Frontal crest.*

Crista lacrimalis posterior.	*Posterior lacrimal crest.*
Decussatio nervorum trochlearium.	*Decussation of trochlear nerves.*
Ductuli excretorii (gl. lacrimalis).	*Excretory duct (lacrimal gland).*
Ductus lacrimales.	*Lacrimal duct.*
Ductus nasolacrimalis.	*Naso lacrymal duct.*
Endothelium camerae anterioris.	*Endothelium of anterior chamber.*
Epithelium corneae.	*Epithelium of cornea.*
Epithelium lentis.	*Lens epithelium.*
Excavatio papillae n. optici.	*Physiologic cup of disk.*
Facies anterior.	*Anterior Wall or Surface.*
Facies anterior lentis.	*Anterior surface of lens.*
Facies anterior palpebrarum.	*Anterior surface of lid.*
Facies cerebralis.	*Wall of brain.*
Facies frontalis.	*Frontal surface.*
Facies orbitales.	*Orbital walls.*
Facies orbitalis.	*Orbital wall.*
Facies (ossea).	*Surface (Bones).*
Facies posterior.	*Posterior surface.*
Facies posterior lentis.	*Posterior surface of lens.*
Facies posterior palpebrarum.	*Posterior surface of lids.*
Facies temporalis.	*Temporal wall.*
Fascia bulbi (Tenoni).	*Fascia covering of bulb (Capsula of Tenon).*
Fasciae musculares.	*Muscular coverings.*
Fibrae circulares (Muelleri).	*Circular fibers (of Mueller).*
Fibrae lentis.	*Lens fibers.*
Fibrae meridionales (Bruecki).	*Meridional fibers (of Brueck).*
Fibrae zonulares.	*Zonule fibers.*
Fissura orbitalis inferior.	*Inferior orbital fissure.*
Fissura orbitalis superior.	*Superior orbital fissure.*
Foramen caecum.	*Caecum foramen.*
Foramen ethmoidale anterius.	*Anterior ethmoidal foramen.*
Foramen ethmoidale posterius.	*Posterior ethmoidal foramen.*
Foramen opticum.	*Optic foramen (canal).*
Foramen sive incisura.	*Foramen or hole.*
Fornix conjunctivae inferior.	*Lower fornix of conjunctiva.*
Fornix conjunctivae superior.	*Upper fornix of conjunctiva.*
Fornix sacci lacrimalis.	*Border lacrimal sac.*
Fossa cerebri lateralis.	*Lateral fossa (excavation) of brain.*
Fossa glandulae lacrimalis.	*Fossa of lacrymal gland.*
Fossa Hyaloidea.	*Hyaloid fossa.*
Fossa sacci lacrimalis.	*Fossa of lacrimal sac.*
Fovea centralis.	*Central yellow spot.*
Fovea trochlearis.	*Trochlear Fovea.*

Frontale.	*Frontal.*
Funiculus sclerae.	*Strands of N. Fibres in region of fovea centralis.*
Ganglion interpedunculare.	*Interpeduncular ganglion.*
Ganglion Nervi optici.	*Ganglion cells of optic nerve.*
Ganglion oticum.	*Optic ganglion.*
Ganglion semilunare (Gasseri).	*Semilunar ganglion (Gasserian).*
Glabella.	*Glabella (flat place).*
Glandula lacrimalis inferior.	*Lower lesser lacrimal gland.*
Gl. lacrimalis superior.	*Upper (greater) lacrimal gland.*
Gl. lacrimales accessoriae.	*Accessory lacrimal glands.*
Gl. mucosae (Krausei).	*Mucous glands (of Krause).*
Gl. tarsales (Meibomi).	*Tarsal glands (Meibomian).*
Gyri occipitales superiores.	*Superior occiupital gyrus.*
Gyri orbitales.	*Orbital gyri.*
Hamulus lacrimalis.	*Hamulus process lacrymal bone.*
Humor vitreus.	*Vitreous body (humor).*
Incisura ethmoidalis.	*Ethmoidal notch.*
Incisura sive Foramen.	*Hole or foramen.*
Infraorbitalis.	*Infraorbital.*
Irides.	*Plural of Iris.*
Lacertus musculi recti lateralis.	*Muscular portion of external rectus.*
Lacrimae.	*Tears.*
Lacus lacrimalis.	*Lacrimal lake (depression).*
Lamina basalis.	*Base layer (Plate).*
Lamina choriocapillaris.	*Choroid capillary layer.*
Lamina choriodea epithelialis.	*Choroid epithelial layer.*
Lamina cribrosa sclerae.	*Cribiform layer of sclera.*
Lamina elastica anterior (Bowmani).	*Anterior elastic layer (of Bowman).*
Lamina elastica posterior (Demoursi, Descemeti).	*Posterior elastic layer (of Demoursi, Decemet).*
Lamina fusca.	*Dark layer.*
Lamina papyracea.	*Paper Plate.*
Lamina quadrigemina.	*Quadrigeminal layer.*
Lamina suprachoriodea.	*Supra-choroid layer.*
Lamina vasculosa.	*Vascular layer.*
Lemniscus.	*Fillet.*
Lemniscus lateralis.	*Lateral fillet.*
Lemniscus medialis.	*Inner fillet.*
Lens crystallina.	*Crystalline lens.*
Lig. palpebrale mediale.	*Inner (medial) palpebral (lid) ligament.*
Lig. pectinatum iridis.	*Pectinate ligament of iris.*

Limbi palpebrales anteriores.	*Anterior lid borders.*
Limbi palpebrales posteriores.	*Posterior lid borders.*
Limbus corneae.	*Border of cornea.*
Linea temporalis.	*Temporal line.*
Linea visus.	*Visual line.*
Lobus parietalis.	*Parietal lobe.*
M. ciliaris.	*Ciliary muscle.*
M. dilatator pupillae.	*Dilator muscle of pupil.*
M. levator palpebrae superioris.	*Elevating muscle of upper lid.*
M. obliquus inferior.	*Lower oblique muscle.*
M. obliquus superior.	*Upper oblique muscle.*
M. orbicularis oculi.	*External sphincter muscle of eye.*
M. orbitalis.	*Orbital muscle.*
M. rectus inferior.	*Inferior rectus muscle.*
M. rectus lateralis.	*Lateral (outer) rectus muscle.*
M. rectus medialis.	*Medial (inner) rectus muscle.*
M. rectus superior.	*Upper rectus muscle.*
M. sphincter pupillae.	*Sphincter (contractor) muscle pupil.*
M. tarsalis inferior.	*Inferior (lower) muscle of lid (tarsus)*
M. tarsalis superior.	*Superior (upper) muscle of lid (tarsus)*
Macula lutea.	*Yellow spot.*
Margo ciliaris.	*Ciliary margin (edge).*
Margo infraorbitalis.	*Lower orbital margin.*
Margo lacrimalis.	*Lacrimal margin.*
Margo nasalis.	*Nasal margin.*
Margo orbitae.	*Margin of orbit.*
Margo parietalis.	*Temple margin.*
Margo pupillaris.	*Pupil margin.*
Margo supraorbitalis.	*Upper orbit margin.*
Maxillae.	*Upper jaw bones.*
Membrana hyaloidea.	*Hyaloid membranes.*
Membrana limitans externum and internum.	*Limiting membrane external and internal.*
Membrana pupillaris.	*Pupillary membrane.*
Meridiani.	*Meridian.*
Mesencephalon.	*Middle brain.*
Musculi oculi, fasciae orbitales.	*Eye muscle, orbital fascia.*
N. ethmoidalis anterior.	*Anterior ethmoidal nerve.*
N. ethmoidalis posterior.	*Posterioe ethmoidal nerve.*
N. frontalis.	*Frontal nerve.*
N. infratrochlearis.	*Infra-trochlear nerve.*
N. lacrimalis.	*Lacrimal nerve.*

N. nasociliaris.	*Naso-ciliary nerve.*
N. oculomotorius.	*Oculo-motor nerve.*
N. ophthalmicus.	*Ophthalmic nerve.*
N. opticus.	*Optic nerve (2nd cranial nerve.)*
N. supratrochlearis.	*Supra-trochlea nerve.*
N. tentorii.	*Tentorium nerve.*
N. trigeminu.	*Trigeminal (trifacial or 5th) nerve.*
N. trochlearis.	*Trochlear nerve.*
Nn. ciliares breves.	*Short ciliary nerves.*
Nn. ciliares longi.	*Long ciliary nerves.*
Nervi cerebrales.	*Cerebral nerves.*
Noduli lymphatici conjunctivales.	*Lyphatic nodules of conjunctiva.*
Nucleus lentis.	*Lens nucleus.*
Nucleus n. trochlearis.	*Trochlear nerve nucleus.*
Nucleus ruber.	*Red neucleus.*
Oculus.	*Eye.*
Ora serrata.	*Serrated edges.*
Orbiculus ciliaris.	*Ciliary disc.*
Orbita.	*Orbit.*
Organa oculi accessoria.	*Accessory organs of eye.*
Organa sensuum et integumentum commune.	*Sense organ, Skin common*
Organon visus.	*Visual organ.*
Os ethmoidale.	*Ethmoid bone.*
Os frontale.	*Frontal bone.*
Os lacrimale.	*Lacrimal bone.*
Os palatinum.	*Palate bone.*
Os sphenoidale.	*Sphenoid bone.*
Os temporale.	*Temporal bone.*
Os zygomaticum, ossa zygomatica.	*Zygomatic bone, zygomatic bones.*
Ossa cranii.	*Cranial bones.*
Ossa faciei.	*Facial bones:*
Palpebra inferior.	*Lower lid.*
Palpebra superior.	*Upper lid.*
Palpebrae.	*Lids.*
Papilla n. optici.	*Disk of optic nerve (Disk).*
Papillae lacrimales.	*Lacrimal papilla.*
Paries inferior.	*Inferior (lower) wall.*
Paries lateralis.	*Lateral (outer) wall.*
Paries medialis.	*Medial (nasal) wall.*
Paries superior.	*Superior (upper) wall.*
Pars ciliaris retinae.	*Ciliary part of retinal (retinal pigment).*

Pars lacrimalis (Horneri).	*(Lacrymal part) (muscle) (of Horner).*
Pars nasalis.	*Nasal part (of Horner's muscle).*
Pars optica retinae.	*Seeing portion of retina.*
Pars orbitalis.	*Orbital part.*
Pars palpebralis.	*Lid part.*
Periorbita.	*Periosteum of orbit.*
Pinguecula.	*Yellow deposit on anterior sclera.*
Planum orbitale.	*Orbital plane.*
Plexus caroticus internus.	*Internal caroted plexus.*
Plexus gangliosus ciliaris.	*Ciliary ganglion plexus.*
Plica lacrimalis (Hasneri).	*Lacrimal plica (of Hasner).*
Plica semilunaris conjunctivae.	*Semilunar plica of conjunctiva.*
Plicae ciliares.	*Ciliary folds.*
Plicae iridis.	*Iris folds.*
Polus anterior.	*Anterior pole.*
Polus anterior lentis.	*Anterior pole of lens.*
Polus posterior.	*Posterior pole.*
Polus posterior lentis.	*Posterior pole of lens.*
Portio major.	*Larger portion.*
Portio minor.	*Smaller portion.*
Processus ciliares.	*Ciliary process.*
Processus zygomaticus.	*Zygomatic process.*
Pulvinar.	*(Cushion) Posterior extremity of thalamus.*
Puncta lacrimalia.	*Lacrymal hole.*
Pupilla.	*Pupil.*
R. palpebralis inferior.	*Lower lid edge.*
Radii lentis.	*Radii of the lens.*
Radix longa gangIii ciliaris.	*Long root of ciliary gangli.*
Rami musculares.	*Muscular arms.*
Rami nasales anteriores.	*Anterior nasal rami.*
Rami nasales interni.	*Internal nasal rami.*
Rami nasales laterales.	*Lateral nasal rami.*
Rami nasales mediales.	*Medial nasal branches.*
Ramus anastomaticus cum n. zygomatico.	*Anastomatic branch with zygomatic nerve.*
Ramus inferior.	*Lower ramus.*
Ramus nasalis externus.	*Outer nasal ramus.*
Ramus palpebralis superior.	*Upper lid branch.*
Ramus superior.	*Upper ramus.*
Raphe chorioideae.	*Choroid ligament.*
Raphe palpebralis lateralis.	*Lateral (outer) lid ligament.*
Raphe sclerae.	*Scleral ligament.*

Retina.	*Retina.*
Rima cornealis.	*Corneal edge.*
Rima palpebrarum.	*Edge lid.*
Rivus lacrimalis.	*Lacrimal passage.*
S. Radix brevis ganglii.	*Short root of S. Ganglion.*
Saccus lacrimalis.	*Lacrimal Sac.*
Sclera.	*Sclera.*
Sebum palpebrale.	*Lid Sebum (an excretion of meibomian glands).*
Septum orbitale.	*Orbital septum.*
Septum sinuum frontalium.	*Septum of frontal sinuses.*
Sinus frontalis.	*Frontal sinus.*
Sinus venosis sclerae (canalis Schlemmi, Lauthi).	*Schlemm's Canal.*
Spatia anguli iridis (Fontanae).	*Spaces of Fontana.*
Spatia intervaginalia.	*Intervaginal space.*
Spatia zonularia.	*Zonular spaces.*
Spatium interfasciale (Tenoni).	*Tenon's space, interfascial space.*
Spatium perichorioideale.	*Peri-choroidal space.*
Spina frontalis.	*Frontal spine.*
Spina trochlearis.	*Trochlear spine.*
Squama frontalis.	*Frontal plate.*
Stratum bacillorum.	*Layer rods and cones.*
Stratum opticum.	*Optic (nerve) layer.*
Stratum Granularum externum	*External granular layer.*
Stratum Granularum internum or ganglion retinae.	*Internal granular layer.*
Stratum nigrum.	*Black pigment layer.*
Stratum pigmenti.	*Pigment layer.*
Stratum pigmenti corporis ciliaris.	*Pigment layer of ciliary body.*
Stratum pigmenti iridis.	*Pigment layer of iris.*
Stratum pigmenti retinae.	*Pigment layer of retina.*
Stratum retuculare externum.	*External nuclear layer.*
Stratum reticulare internum.	*Internal nuclear layer.*
Stria medullaris.	*Medulla strips.*
Stroma iridis.	*Body (structure) of iris.*
Stroma vitreum.	*Structure vitreous.*
Substantia corticalis.	*Cortical substance.*
Substantia lentis.	*Lens substance.*
Substantia nigra.	*Black substance.*
Substantia propria.	*Proper (regular) substance.*
Sulci occipitales laterales.	*Lateral occipital grooves (indentations).*
Sulci orbitales.	*Orbital grooves.*

Sulcus infraorbitalis.	*Infra orbital groove.*
Sulcus lacrimalis.	*Lacrimal groove.*
Sulcus n. oculomotorii.	*Groove for occulomotor nerve.*
Súlcus sagittalis.	*Center (middle) groove.*
Sulcus sclerae.	*Scleral groove.*
Supercilium.	*Eyebrow.*
Supraorbitalis.	*Above the orbit.*
Sutura ethmoideomaxillaris.	*Ethmoid maxillary suture (crack).*
Sutura frontalis.	*Frontal suture (junction of bone).*
Sutura frontoethmoidalis.	*Frontal ethmoid sutura (junction).*
Sutura frontolacrimalis.	*Frontal lacrimal suture junction.*
Sutura frontomaxillaris.	*Frontal maxillary junction.*
Sutura nasofrontalis.	*Nasal frontal junction.*
Sutura parietomastoidea.	*Parietal mastoid junction.*
Sutura sphenomaxillaris.	*Sphenoid maxillary junction.*
Sutura sphenozygomatica.	*Sphenoid molar junction.*
Sutura squamosa.	*Flat suture (junction).*
Sutura squamosomastoidea.	*Junction of flat portion of mastoid bone.*
Sutura zygomaticofrontalis.	*Molar frontal suture.*
Sutura zygomaticomaxillaris.	*Molar maxilla junction.*
Sylvii.	*Of Sylvius.*
Systema lymphaticum.	*Lymphatic system.*
Systema nervorum periphericum.	*Peripheral (outer border) nervous system.*
Taenia thalami.	*Tail of thalamus.*
Tarsus inferior.	*Lower tarsal plate.*
Tarus superior.	*Upper tarsal plate.*
Thalamus.	*Thalamus.*
Trochlea.	*Pulley.*
Tuberculum anterius thalami.	*Anterior swelling of thalamus.*
Tuber frontale.	*Frontal swelling (lump).*
Tuber maxillare.	*Maxillary swelling.*
Tunica conjunctiva bulbi.	*Conjunctiva covering of eyeball.*
Tunica conjunctiva palpebrarum.	*Conjunctiva covering of lids.*
Tunica fibrosa oculi.	*Fibrous covering of eyeball (sclera).*
Tunica vasculosa oculi.	*Vascular covering of eye (choroid coat).*
V. angularis.	*Angular vein.*
V. centralis retinae.	*Central vein of retina.*
V. ethmoidalis anterior.	*Anterior ethmoidal vein.*
V. ethmoidalis posterior.	*Posterior ethmoidal vein.*
V. facialis anterior.	*Anterior facial vein.*
V. facialis communis.	*Common facial vein.*

V. labialis inferior.	*Lower vein of lips.*
V. labialis superior.	*Upper vein of lips.*
V. lacrimalis.	*Lacrimal vein.*
V. nasales externae.	*External nasal vein.*
V. nasofrontalis.	*Naso frontal vein.*
V. ophthalmica inferior.	*Lower opthalmic vein.*
V. ophthalmica superior.	*Upper opthalmic vein.*
V. palpebrales inferiores.	*Lower lid vein.*
V. palpebrales superiores.	*Upper lid vein.*
V. supraorbitalis.	*Above orbit vein.*
Vv. ciliares anteriores.	*Anterior ciliary veins.*
Vv. ciliares posteriores.	*Posterior ciliary veins.*
Vv. conjunctivales anteriores.	*Anterior conjunctival veins.*
Vv. conjunctivales posteriores.	*Posterior conjunctival veins.*
Vv. episclerales.	*Episcleral veins.*
Vv. frontales.	*Frontal veins.*
Vv. musculares.	*Muscle veins.*
Vv. palpebrales.	*Lid veins.*
VV. vorticosae.	*Vortex veins (vena vorticossa).*
Vaginae n. optici.	*Opening of optic nerve.*
Vasa lymphatica.	*Lymphatic vessels (space).*
Vasa sanguinea retinae.	*Lymph space of retina.*
Vena-venae.	*Vein-veins.*
Vertex corneae.	*Anterior mid point of cornea.*
Vesicula ophthalmica.	*Ophthalmic vessicles.*
Zonula ciliaris (Zinni).	*Zonule of Zinn.*

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